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The Windy Island Soliton Experiment (WISE): Shallow Water and Basin Experiment Configuration and Preliminary Observations

by

Christopher W. Miller
Marla Stone
Keith Wyckoff
Fred Bahr

19 February, 2009

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Prepared for: Office of Naval Research, Ocean Acoustics Division (Code 321)
875 North Randolph Street, Suite 1425
Arlington, Virginia 22203-1995

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NAVAL POSTGRADUATE SCHOOL
Monterey, California 93943-5000

This report was prepared for, and funded by the Office of Naval Research, Ocean Acoustics Division (Code 321).

This report was prepared by:

____
Christopher W. Miller
Research Associate

____
Marla Stone
Oceanographer

____
Keith Wyckoff
Technician

____
Fred Bahr
Research Associate

Reviewed by:

____
Jeff Paduan
Department of Oceanography

Released by:

____
Karl A. van Bibber
Vice President and
Dean of Research

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13. ABSTRACT *(maximum 200 words)*

The Windy Islands Soliton Experiment (WISE) was designed by Taiwan and US physical oceanographers to observe the generation, evolution and transformation of the transbasin, nonlinear internal waves in the Northeastern South China Sea for a period of one year beginning April 2005. To augment the naval relevance of WISE, specifically in the area of antisubmarine warfare, two acoustic propagation studies, one over the shallow shelf and one over the deep basin along the WISE mooring transect were conducted. The objective of the shelf transmission was to study the physics of sound propagation through nonlinear, elevation internal waves in shallow water, and to quantify the associated fluctuations in the sound intensity. The objective of the basin transmission was to study and characterize the supertidal-to-seasonal-scale impacts of the transbasin, nonlinear internal waves on long-range transmission loss, and to help monitor the evolution of the transbasin internal waves in the basin's interior.

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1.0 Introduction

The Windy Islands Soliton Experiment (WISE) was designed to observe the generation, evolution and transformation of transbasin, nonlinear internal waves in the Northeastern South China Sea for a period of one year beginning April 2005. To augment the naval relevance of WISE, specifically in the area of antisubmarine warfare, two acoustic propagation studies, one over the shallow shelf and one over the deep basin along the WISE mooring transect were conducted. The objective of the shelf transmission was to study the physics of sound propagation through nonlinear, elevation internal waves in shallow water, and to quantify the associated fluctuations in the sound intensity. The objective of the basin transmission was to study and characterize the supertidal-to-seasonal-scale impacts of the transbasin, nonlinear internal waves on long-range transmission loss, and to help monitor the evolution of the transbasin internal waves in the basin's interior.

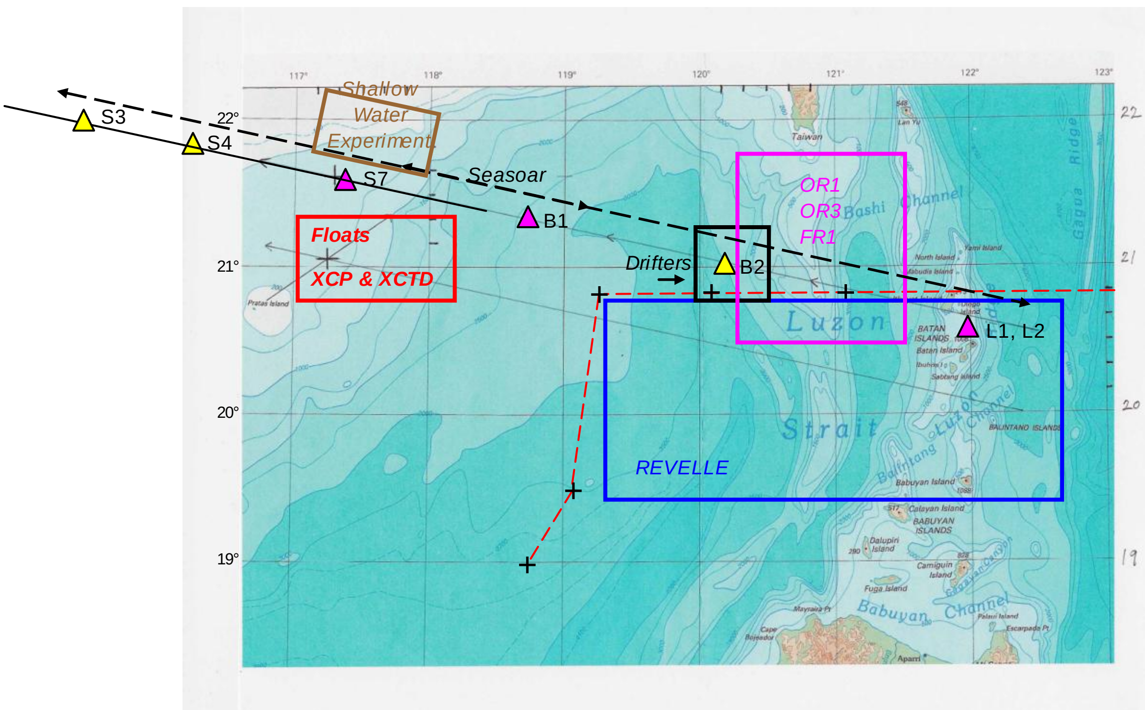


Figure 1. Locator map showing the locations of all physical oceanography (PO) moorings proposed by Ramp, Tang and Yang. An "S" indicates continental shelf moorings, a "B" the deep basin moorings, and an "L" the Luzon Strait mooring. Moorings in yellow are to be deployed by Taiwan and magenta by NPS.

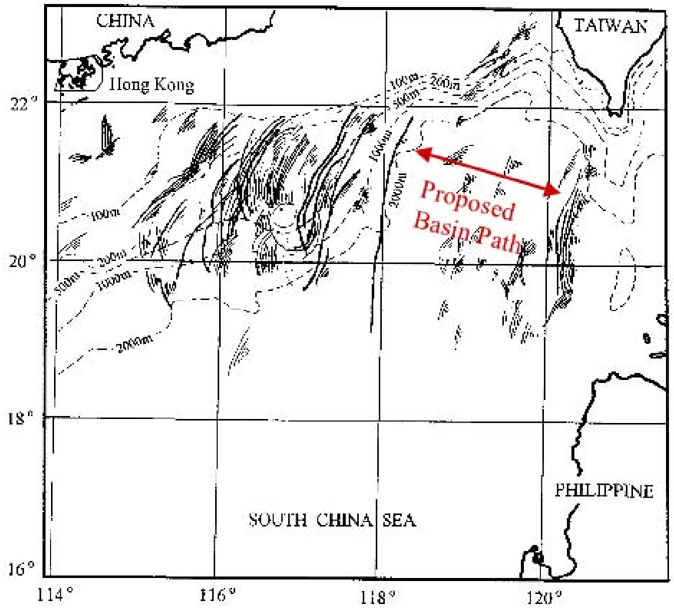


Figure 2. Composite sketch of the spatial distribution of nonlinear internal waves in the NE SCS based on SAR images (Liu, NASA). Superimposed in red is the proposed reciprocal basin transmission path.

2.0 Personnel

Table 1. OR1 scientific personnel, April-May 2005.

April 12-21,2005	April 24 – May 1, 2005
Joe Wang (Chief Scientist)	Y. J. Yang
Ching-Sang Chiu (NPS)	Steve Ramp (NPS)
Marla Stone (NPS)	Chris Miller (NPS)
Chris Miller (NPS)	Marla Stone (NPS)
Keith Wyckoff (NPS)	Ben Reeder (NPS)
Glen Gawarkiewicz (WHOI)	Keith Wyckoff (NPS)
Frank Bahr (WHOI)	Wen-Hwa Her
Craig Marquette (WHOI)	J.H. Tai
Dave Nelson (URI, scanfish)	K.C. Yang
Lou St. Laurent (FSU)	Y.T. Chang
Kevin Speer (FSU)	Y.K. Chen
Peter Lazarevich (FSU)	H.F. Lu
Linus Chiu (NTU student)	Y.L. Yeh

Table 2. OR1 scientific Personnel, July 2005.

July 21-28, 2005	
Yiing Jang Yang	Associate Professor, CAN
Steve Ramp	Professor, NPS
Justin Reeves	PhD student, NPS
Marla Stone	Oceanographer, NPS
Chris Miller	Research Associate, NPS
Keith Wyckoff	Physical Science Technician, NPS
Fred Bahr	Research Associate, NPS
Eerin Sousa	Engineer, URI
Wen-Hwa Ho	Technician, NTU
Kai-Chieh Yang	MD student, NTU
Ya-Ting Chang	MD student, NTU
Yu-Kai Chen	MD student, NTU
Ming-Hong Lin	MD student, NTU
Hong-Fu Lu	MD student, NTU
Chung-Wu Wang	Assistant Professor, CCMTC

Figure 3. National Taiwan University Research Vessel Ocean Researcher I

3.0 Shelf Experiment Equipment

The purpose of the continental shelf component of the WISE acoustic transmissions was to

study the physics of sound propagation through nonlinear, elevation internal waves in shallow water, and to quantify the associated fluctuations of the sound intensity. This experiment was conducted over a 3-day period, prior to the basin transmissions.

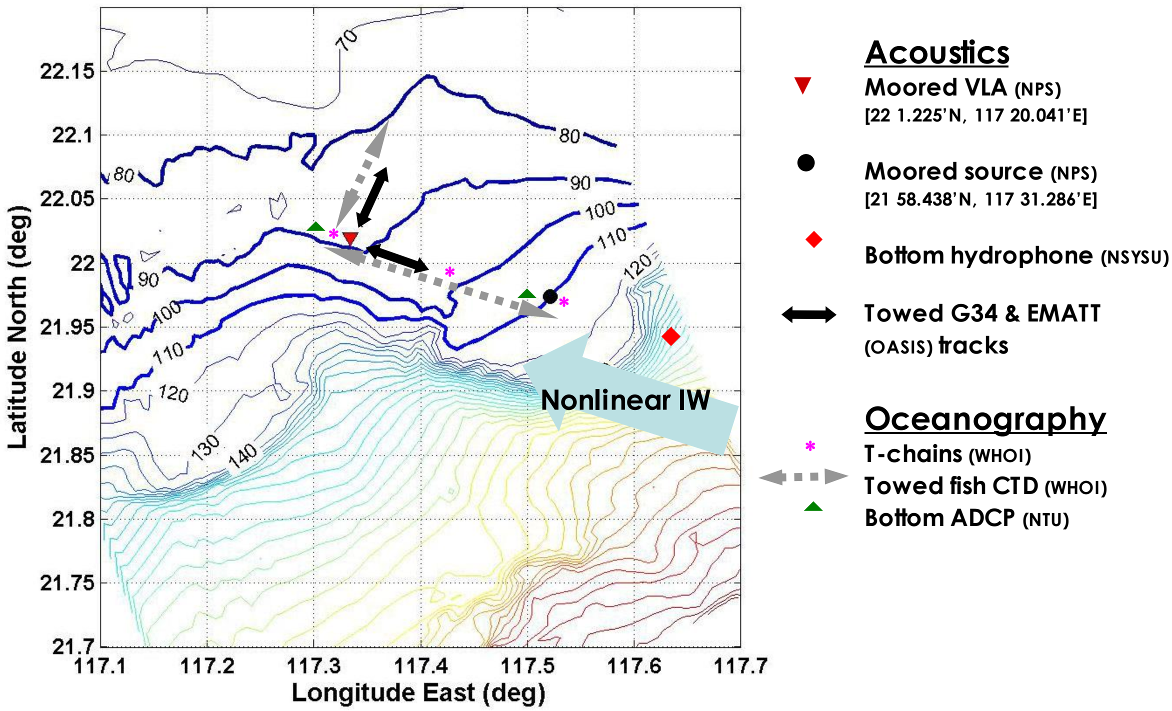


Figure 4. Planned configuration for the shallow water experiment. The black circle along the 110m isobath is the NPS 400 Hz sound source. The red triangle is the proposed location for the 8 channel, 56m aperture VLA mooring, 20km from the source.

3.1 NPS 400 Hz SYS13 sound source (shelf transmissions)

The sound source used during the shelf experiment was a 400 Hz source manufactured by Webb Research Corporation (WRC) belonging to NPS. This source has 100 Hz bandwidth, and transmits a 5.11 second, 511 digit pseudo-random (m-sequence) signal at 180 dB//1μPa. The targeted path length for the 400 Hz signals was 20km to the vertical line array, however due to depth constraints on the moorings a final path length of 15 km was used during deployment.

To provide sufficient sampling for soliton elevation wave study, this source transmitted for 2.55 minutes every 5 minutes. The power supply for this source is comprised of 45 volt, 14 amp-hour battery pucks, wired in parallel to provide the total power required to conduct the experiment. For the shelf experiment transmission schedule, the total power required is 29.6 MJ, and requires a battery pack size of 16 pucks.

Table 3. NPS 400 Hz source deployment information

System Address	'SYS13'
Deployed (date/time UTC)	4/12/05, 20:04
Recovered (date/time UTC)	4/16/05, 03:00
Latitude N (anchor drop)	21° 57.4692' N
Longitude E (anchor drop)	117° 30.3852' E
Water depth (m)	110 m
Source depth (m)	100 m
Latitude N (surveyed)	21° 57.4549' N
Longitude E (surveyed)	117° 30.3557' E

Table 4. NPS 400 Hz source deployment and recovery time checks (clock #66) showed that the clock slowed 21.58 ms over 4.577 days (-4.715 ms/day).

System time (UTC) DDD HH MM SS	GPS SAIL time (UTC) DDD HH MM SS.SSSSSS
102 18:29:47	102 18:29:55.184459
107 08:21:14	107 08:21:22.206043

Table 5. NPS 400 Hz (SYS13) shelf transmission schedule.

Start time (UTC)	YD 103 23:00
Transmission times (minutes after the hour)	0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55
Center frequency (Hz)	400
Bandwidth (Hz)	100
Source level	180 dB re 1 μPa @ 1m
Cycles per digit	4
Digit width	10 ms
Digits per sequence (sequence length)	511 (5.11 s)
Number of sequences transmitted	30 (153.3 s)
m-sequence LAW (octal)	1473
Sequence initialization	000000001
Modulation angle	87.467035°

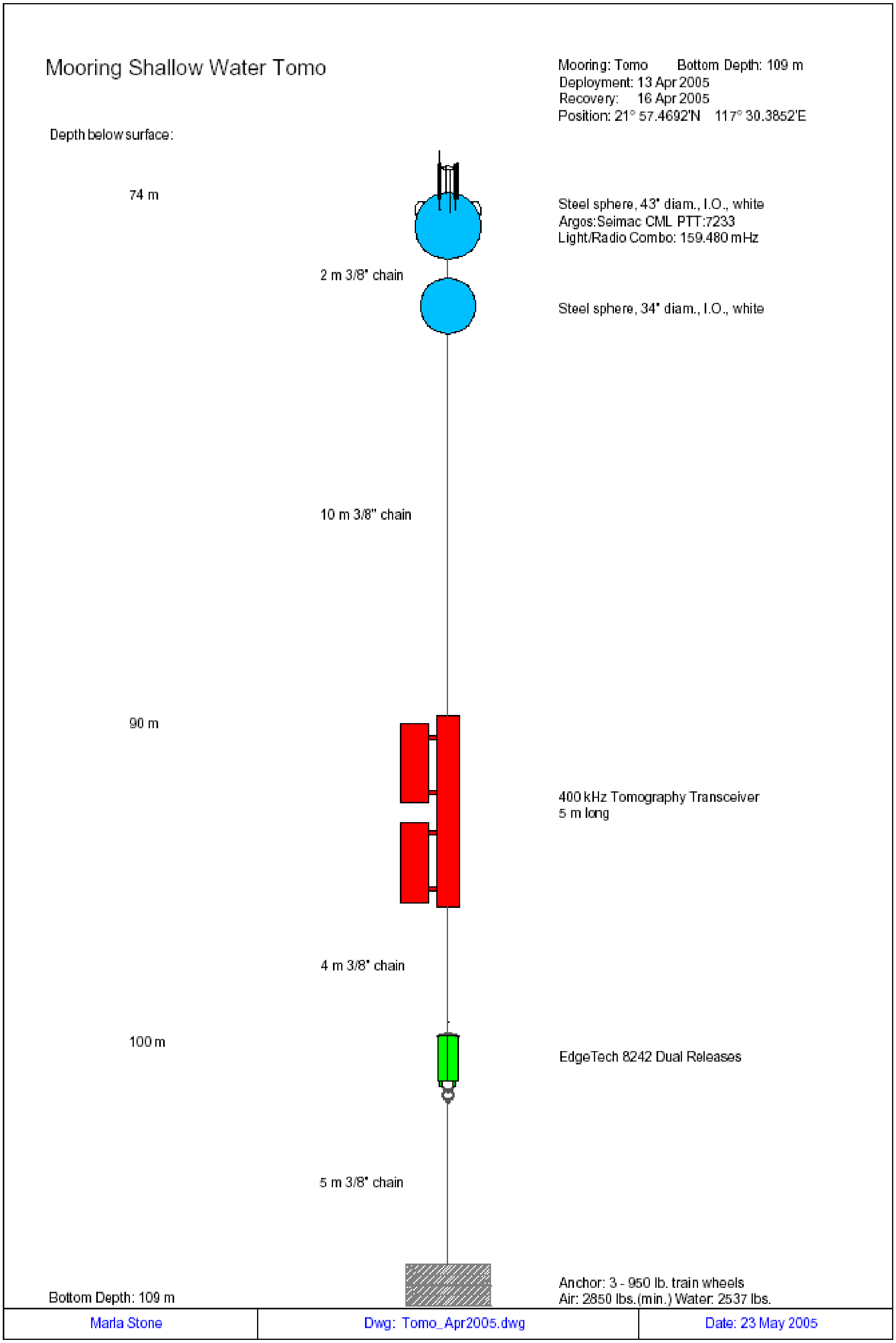


Figure 5. Shallow water tomography source mooring (as deployed).

3.2 *G-34 Towed Source*

The R/V Ocean Researcher Three (OR3) research team (from National Sun Yat-Sen University (NSYSU) and Ocean Acoustical Services and Integrated Systems (OASIS), Inc.) will dip a G-34 broadband acoustic source during the shelf experiment, along and across the soliton propagation path. The G34 source is a low audio transducer, with a frequency range of 200-5,000 Hz, and can operate to depths of 1379 meters. The maximum driving signal is approximately 1000 volts, although maximum levels were not possible due to the 20 volt maximum output of the power amplifiers available during the experiment.

For the WISE experimental setup, the G34 had a source level of approximately 155 dB re 1 uPa @ 1m, and transmitted low frequency, hyperbolic frequency modulated (LF HFM) sweeps from 500-650 Hz bandwidth, as well as Medium frequency hyperbolic frequency modulation signals (MF HFM) between 800-1000 Hz.

The nominal TVR curve for the G34 transducer is shown in figure 6 (courtesy Naval Research Laboratory, Underwater Sound Reference Division).

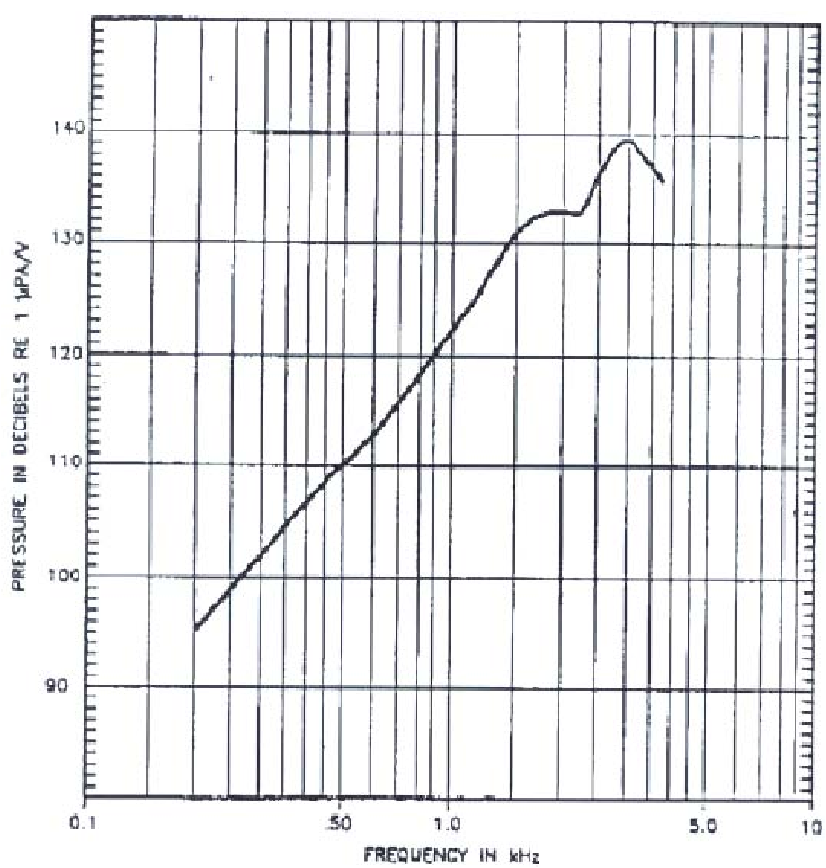


Figure 6. Typical TVR curve for a G34 transducer (from NRL USRD, April 1991).

3.3 Expendable Mobile ASW Training Target (EMATT)

OASIS personnel deployed several EMATT vehicles during the shallow water experiment. EMATT's are manufactured by Sippican, Inc. as an autonomous training target for the Navy. EMATT's are preprogrammed for course, depth (75-600 ft) and speed (3-8 kts) before deployment, and are able to run for 3-8 hours, depending on the speeds selected.

EMATT's deployed during WISE have been modified to transmit hyperbolic FM (HFM) chirps over the bandwidths of 500-650 Hz and 800–1000 Hz. The EMATT signal generator was capable of storing 6 second WAV format audio files for transmission.

Figure 7. Image of an EMATT, after it has been removed from the service launch container.

Table 6. EMATT Signal characteristics

Center Frequency	575 Hz		Center Frequency	900 Hz
Source level	~143 ± 3 dB		Source level	~150 ± 3 dB
Bandwidth	500-650 Hz		Bandwidth	800-1000 Hz
Transmission time	2 s		Transmission time	2 s

3.4 NPS 8 element, vertical line array

During the continental shelf experiment (April 13-15, 2005), an 8 element, vertical line array (VLA) was moored in ~90m of water. The array was manufactured by High Tech, Inc., and is manufactured with HTI-94-SSQ current mode hydrophones with a phone spacing of 8-m for a total acoustic aperture of 56m. The hydrophone preamplifiers are current mode, require 12Vdc, 3.12mA (avg.) power and have a maximum signal output of 1.3Vpp (0.5 Vrms) before clipping occurs. The preamplifiers provide a nominal gain of 28 dB, with a hydrophone sensitivity of -198 dB re 1V/μPa for an array element sensitivity of approximately -170 dB re 1V/μPa. The exact element sensitivities (obtained by comparison to a reference hydrophone) are listed in Table 10. The array has a minimum bend radius of 13 inches.

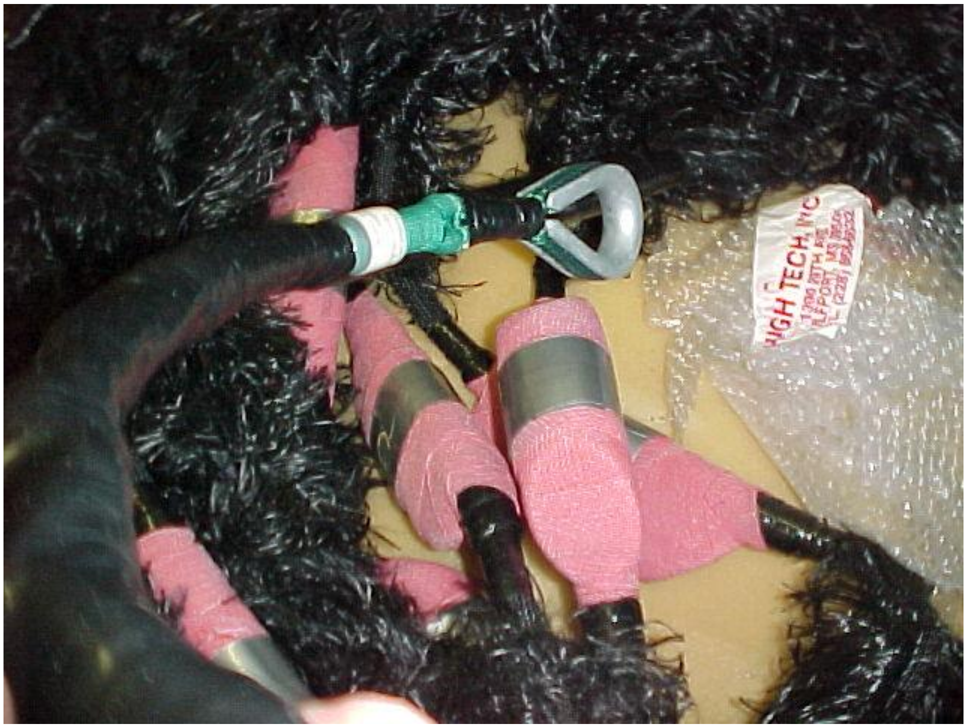


Figure 8. Close up of the VLA hydrophone elements (under pink wrapping), and faired array strength member.

VLA mooring motion was measured using an acoustic interrogator, designed, built, and on loan from Steve Liberatore of the Woods Hole Oceanographic Institution, and an array of three transponders, manufactured by Benthos, Inc. (model TR-6001-13). The interrogator units are modified acoustic release transponders, with specific transmit and receive frequencies.

The array design placed the bottom hydrophone 11.5m above the bottom, so the deployed hydrophone depths were 20.5m, 28.5m, 36.5m, 44.5m, 52.5m, 60.5m, 68.5m and 76.5m.

Table 7. NPS VLA deployment information

Deployed (date/time UTC)	4/13/05 02:30 (2005 YD 103)
Recovered (date/time UTC)	4/15/05, 08:40 (2005 YD 105)
Latitude N (anchor drop)	22° 00.8673’ N
Longitude E (anchor drop)	117° 21.1683’ E
Water depth (m)	88 m
Target phone depths (m)	24, 32, 40, 48, 56, 64, 72, 80
Latitude N (surveyed)	22° 00.837314’ N
Longitude E (surveyed)	117° 21.1310’ E
Water depth (surveyed)	88 m
Phone Depths (surveyed)	20.5, 28.5, 36.5, 44.5, 52.5, 60.5, 68.5 and 76.5 m

Table 8. NPS VLA deployment and recovery time checks.

System time (UTC) DDD HH MM SS	GPS SAIL time (UTC) DDD HH MM SS.SSSSSS
097 07:43:22	097 07:43:22.040559
NONE	No communication with electronics after recovery due to water leakage in pressure hull.

Table 9. VLA system parameters

VLA Digitizer start time (UTC)	YD 103, 00:00:00
Sample rate	2000 Hz
Hydrophone gain settings	35 dB
Recording capacity	80 GBytes (hard disk)

The data acquisition system, “STARmini”, was built by Andrey Morozov of Webb Research Corporation of Falmouth, MA. The system was designed for a 8 channel acquisition at a maximum sample rate of 2 kHz. After recovery, the VLA digitizer did not communicate via the SAIL connector. When the pressure hull was opened the positive pressure was released, and approximately 1/4 cup of seawater was present inside the hull. There was lots of corrosion evident around the SeaCon connectors which penetrate the lower end cap for array connectivity and SAIL communication (the connectors faced down during deployment to be able to connect the VLA below it). Battery voltages on each of the 4 power packs were ~12.4 Vdc, with no sign of battery damage. There was also corrosion on one of the signal processing boards (fuse and some components) which was likely the result of laying the pressure hull down on deck after recovery, exposing it to seawater. The internal hard drive showed no signs of damage, so it was pulled from the digitizer and installed in a PC.

There were 11 data files present on the disk for a total of ~6.5 GBytes of acoustic data (each complete file was ~575 MB each), representing 56.5 hours of data collected. The digitizer continued to collect data for the entire deployment. A quick look of the data files show strong 400 Hz signals throughout the various data files, on all of the hydrophones, however signal dropouts (bad data periods) are evident. The seawater intrusion caused corrosive damage to the SAIL and array penetrating connectors, as well as damage to the “front end” signal processing boards (current mode generation and signal filtering), but the Persistor electronics (primary controller, timing, disk controller) were not damaged during the leak.

Figure 9. VLA on deck, ready for deployment. The VLA "STARmini" electronics package is connected (yellow pressure housing connected to strength member), and the mooring motion interrogator is also shown (far right). (Photo courtesy of Linus Chiu, NTU).

Table 10. Sensitivities of the HTI-94-SSQ current mode hydrophones of the VLA measured by comparison method to Reference Hydrophone #083001, USRD Orlando, FL.

Hydrophone S/N (model HTI-94-SSQ)	**Hydrophone Sensitivity dB re: 1V/µPa**	**Current (mA)**
419001	-170.3	3.18
419002	-170.4	3.12
419003	-170.5	3.10
419004	-170.3	3.18
419005	-170.3	3.21
419006	-170.6	3.13
419007	-170.4	3.11
419008	-170.3	3.17

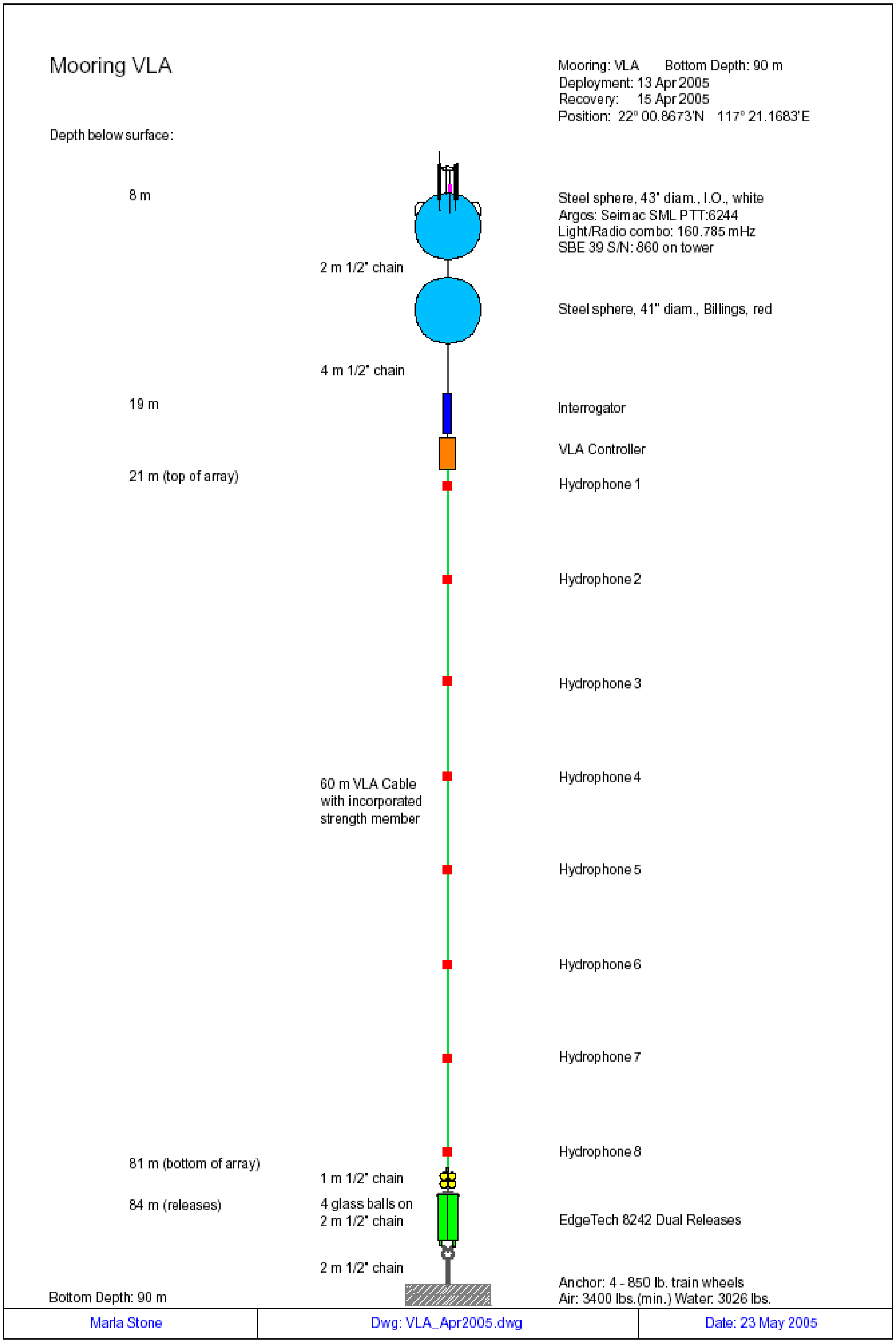


Figure 10. Mooring drawing for the shallow water VLA deployment (as deployed).

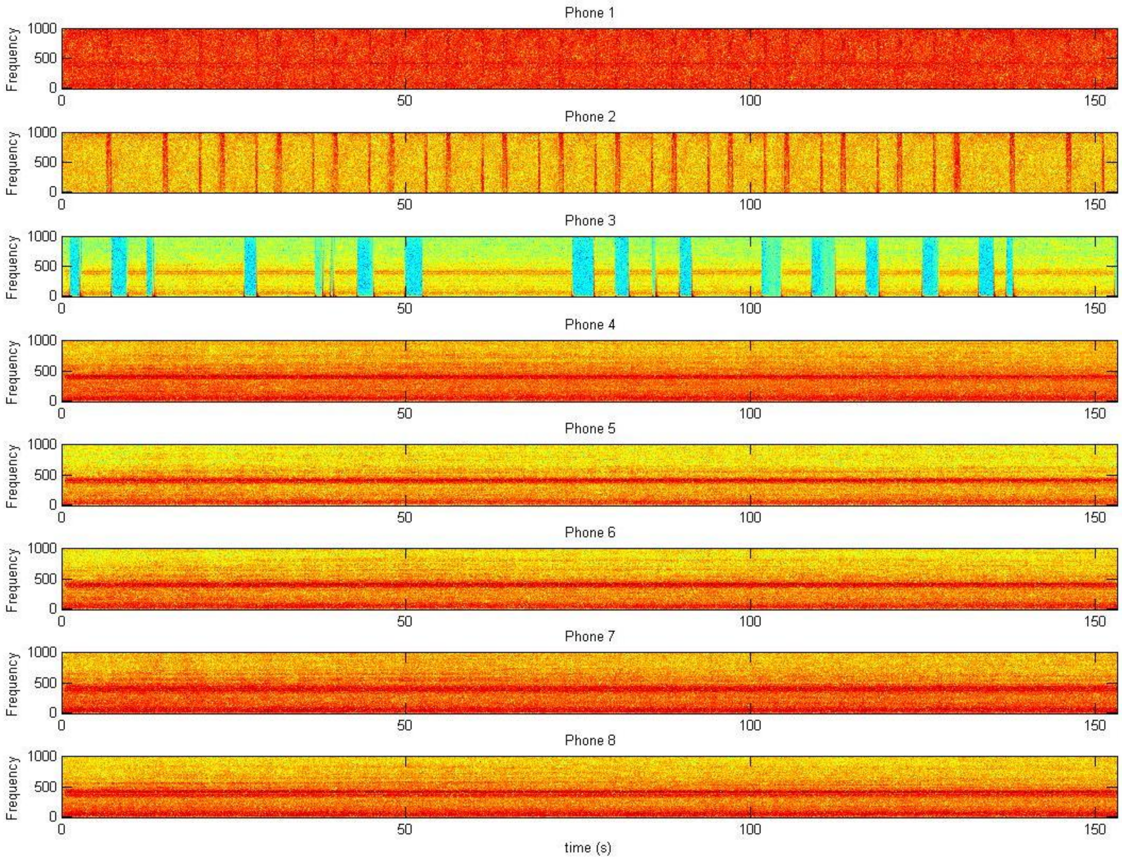


Figure 11. Spectrograms of the eight VLA elements for the 40th tomography transmission. Data gaps are already evident in hydrophone #3, while phone #2 is noisy with continuous clicking. The 400 Hz signal is clearly shown by the dark red, horizontal line on phones #4 - #8.

3.5 Mooring motion measurement

An acoustic Interrogator, designed and built at the Woods Hole Oceanographic Institution, was used to provide mooring motion measurements for the vertical line array. The interrogator recorded round-trip travel times between the interrogator and three bottom-mounted Benthos transponders located around the VLA anchor position. The interrogator was located 1m above the controller electronics on the VLA mooring, 71m above the bottom.

Table 11. VLA Interrogator settings

Serial number/address	#I10
Transmit frequency (acoustic)	10 kHz
Receive frequencies (acoustic)	10.5, 11.0, 11.5 kHz
Interrogator frequency (temporal)	5 minutes
Deployment time check (system)	YD 100 11:49:00
Deployment time check (UTC reference)	YD 100 11:49:00.032119

Benthos model XT-6001, expendable transponders were deployed about the VLA anchor position in a triangular pattern. The targeted distance between the VLA and each transponder location was at least half the water depth at the mooring position. The range to each transponder varied slightly to prevent any ambiguity should the transponder signals arrive at the interrogator at exactly the same time. The transponders have a built in turnaround delay of 3 ms before responding to the interrogated frequency. These units have a source level greater than 192 dB re 1µPa at 1 meter, and have a minimum receive level less than 85 dB re 1 µPa. These units can operate up one year with 200,000 pings (each ping having a 10 ms pulse length), so our 5 minute sampling interval is well within the available power for an entire year's deployment. We are only limited by the available memory in the interrogator units.

Figure 12. Mooring motion components: the WHOI Acoustic Interrogator (foreground), and two Benthos transponders (background).

Table 12. Benthos XT-6001 transponder deployment information

Transponder serial number	#73601	#73599	#73597
Receive frequency (kHz)	10.0	10.0	10.0
Transmit frequency (kHz)	11.5	12.0	12.5
Deployed (date/time UTC)	4/13/05 02:40	4/13/05 02:51	4/13/05 02:55
Latitude N (anchor drop)	22° 00.9084' N	22° 0.8290' N	22° 0.7491' N
Longitude E (anchor drop)	117° 21.1876' E	117° 21.8461' E	117° 21._030' E
Water depth (m)	89 m	89.4 m	89.6 m
Latitude N (surveyed)	22° 00.8917' N	22° 0.8322' N	22° 0.7561' N
Longitude E (surveyed)	117° 21.1744' E	117° 21.0446' E	117° 21.1683' E

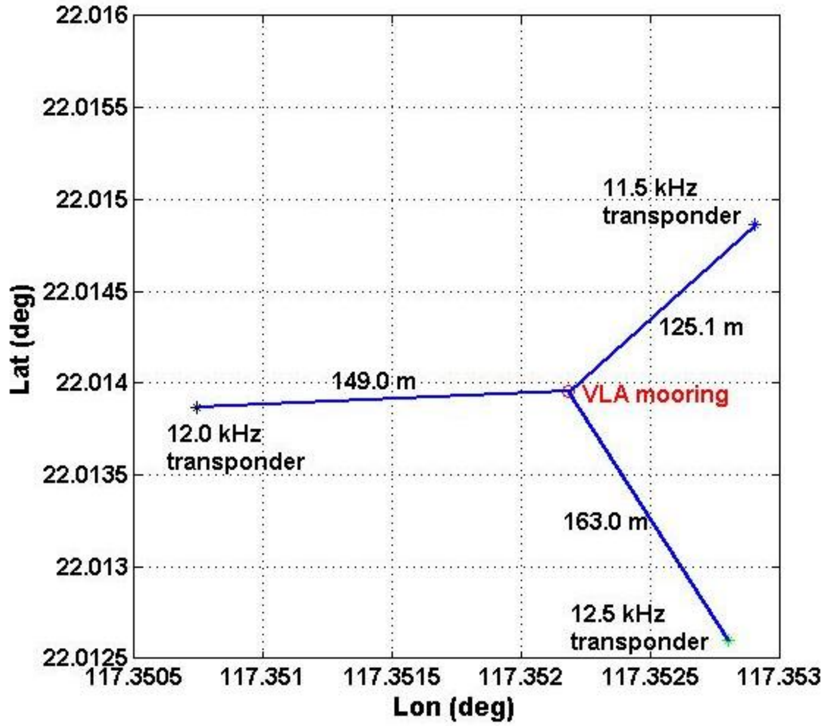


Figure 13. Transponder locations and distances relative to the VLA mooring position.

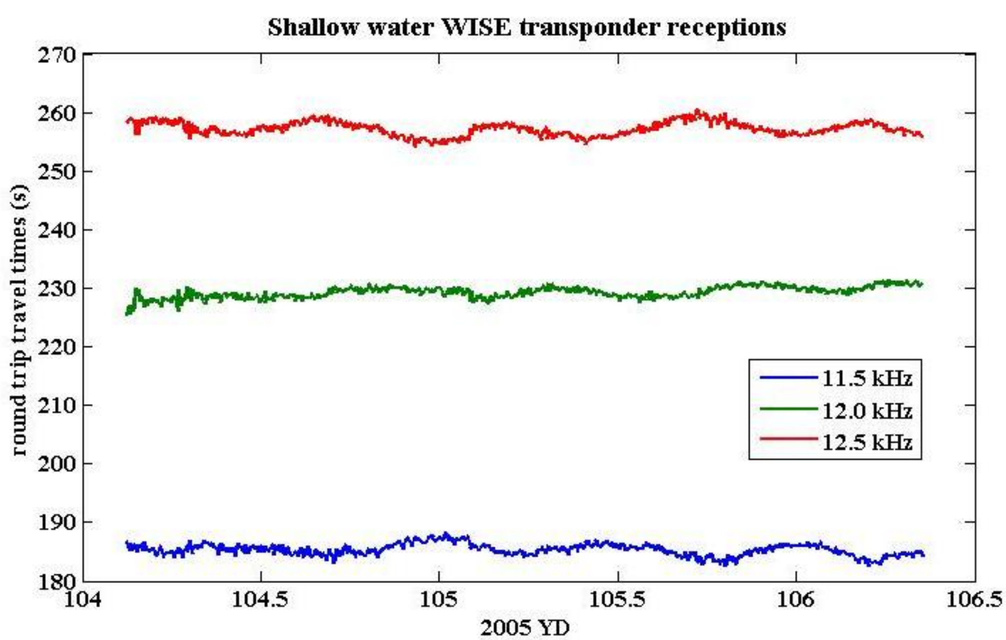


Figure 14. Round-trip travel times as recorded from the WHOI interrogators.

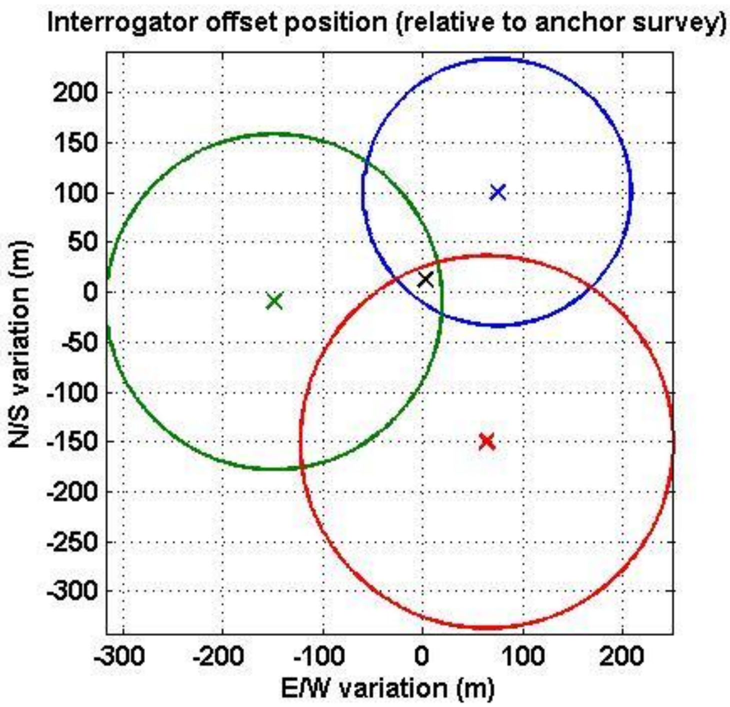


Figure 15. Travel time arcs from the transponders (blue=11.5 kHz, green=12.0 kHz, and red=12.5 kHz) and the calculated interrogator position for this transmission.

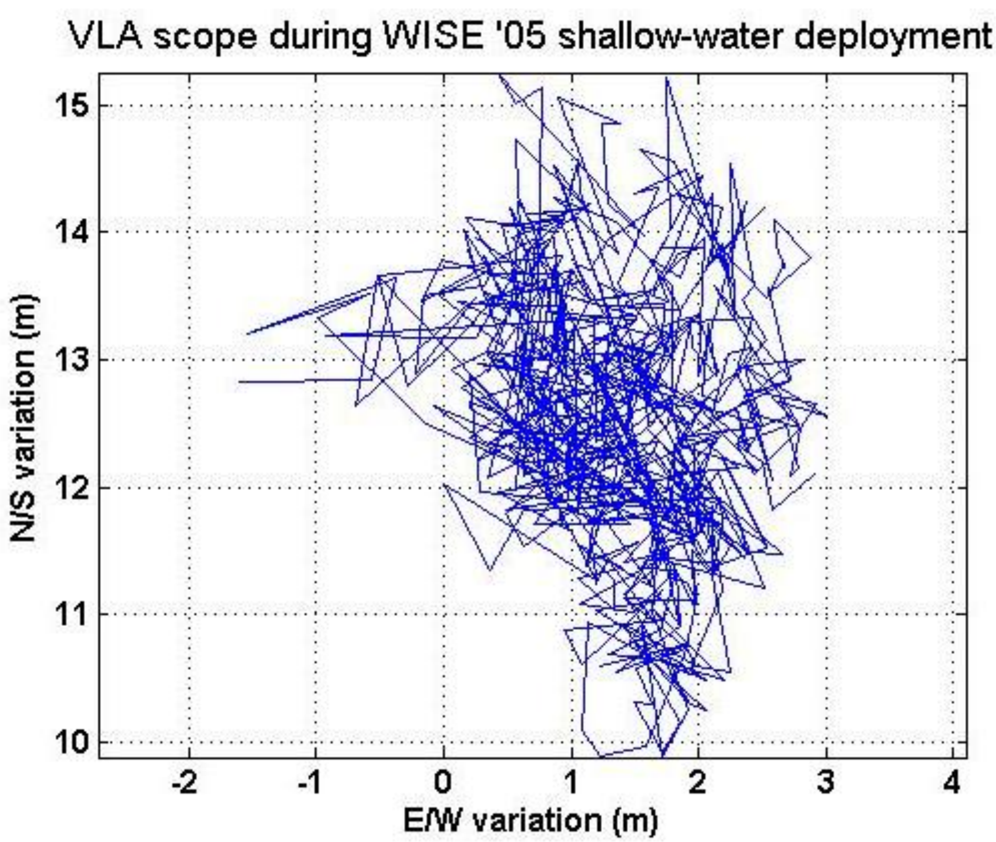


Figure 16. VLA mooring motion (scope) for the April '05 shallow water deployment.

3.6 TidBit Temperature Moorings

Several simple temperature moorings were deployed along the acoustic track of the shallow water experiment. The primary temperature sensor used on these moorings are Onset Computer Corporation's *StowAway TidbiT* temperature logger. The TidbiT units were set to sample at 10 minute intervals. Previous tests of the temperature response of these units was performed by Woods Hole Oceanographic Institution, and the reliable temperature response time of these sensors is roughly 10 minutes. Higher sampling was performed at the 60m depth for each "T" mooring by using a SeaBird 'Seacat' instrument, which sampled every 30 seconds. Additional TidbiT sensors were attached to the VLA near each of the 8 hydrophones, and one on the acoustic interrogator, with a Seacat sensor on the top float (at an average 7m water depth).

Table 13. TidbiT temperature mooring location and sensor depths. The SeaBird sensors for each mooring are listed in bold type.

S mooring		**T1 mooring**		**T2 mooring**		**T3 mooring**		**VLA mooring**	
21° 57.4549' N		21° 57.8948' N		21° 59.1285' N		22° 00.5772' N		22° 0.83731' N	
117° 30.3557' E		117° 27.3683' E		117° 24.0546' E		117° 20.8907' E		117°21.1310' E	
Depth = 110m		Depth = 100m		Depth = 95m		Depth = 90m		Depth = 90m	
S/N	**Depth (m)**	**S/N**	**Depth (m)**	**S/N**	**Depth (m)**	**S/N**	**Depth (m)**	**S/N**	**Depth (m)**
837782	10	837803	10	837793	10	837805	10	**#860**	7
837784	20	837786	20	837795	20	837780	20	837817	19
837779	30	837788	30	837804	30	837811	30	837798	24
837816	40	837809	40	837810	40	837808	40	837813	32
837783	50	837777	50	837801	50	837778	50	837799	40
#1260	60	**#1261**	60	**#1621**	60	**#1755**	60	837790	48
837792	70	837787	70	837800	70	837797	70	837791	56
837796	80	837781	80	837814	80	837818	80	837815	64
837789	90	837819	90	837807	90	837806	87	837794	72
83702	100							837785	80

The TidbiT temperature profiles for each mooring are shown in Figures 17-21. Due to the 10 minute sample frequency and 8-bit quantization only the tides are clearly visible, however much more variability is evident below the 50 m depth, and the SeaBird instruments at 60 m will provide much greater resolution of the passing internal waves.

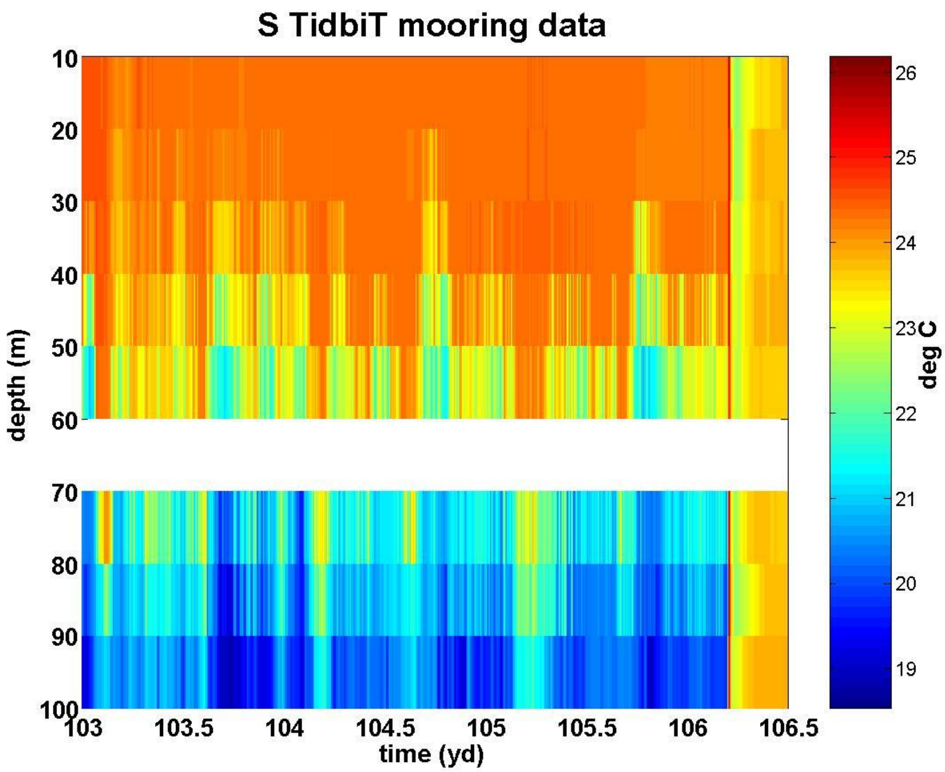


Figure 17. TidbiT temperature data from the mooring collocated at the 400 Hz source location in 110 m of water.

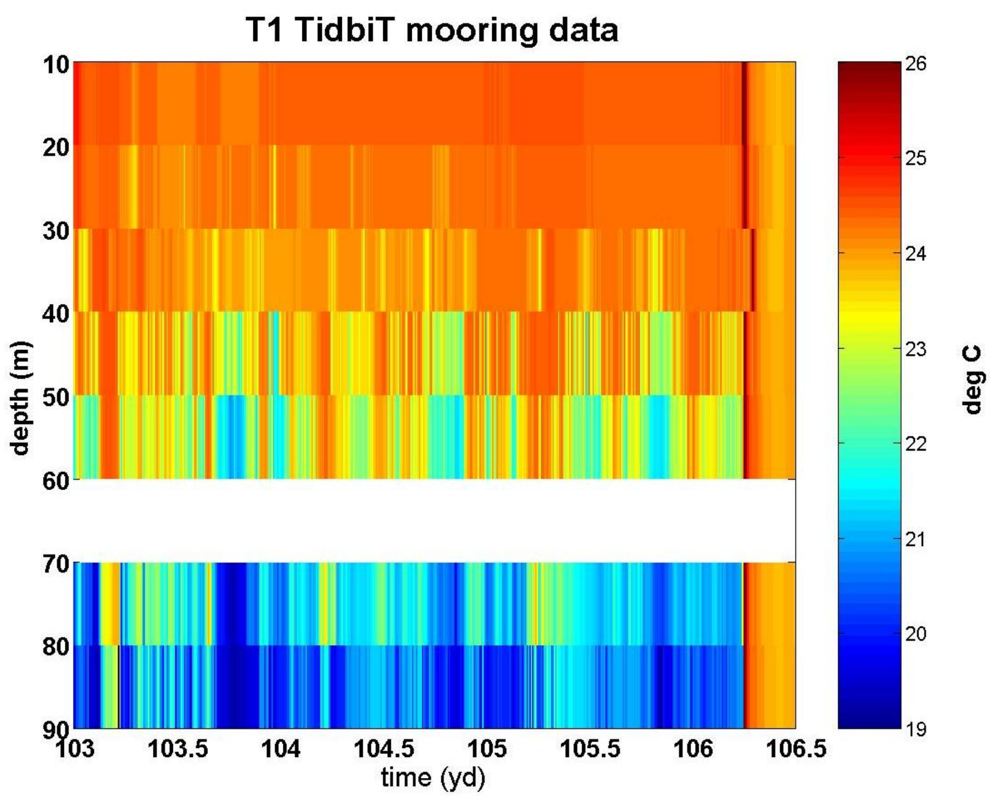


Figure 18. TidbiT temperature data from the T1 mooring lcoation in 97m of water (along the acoustic transmission path)

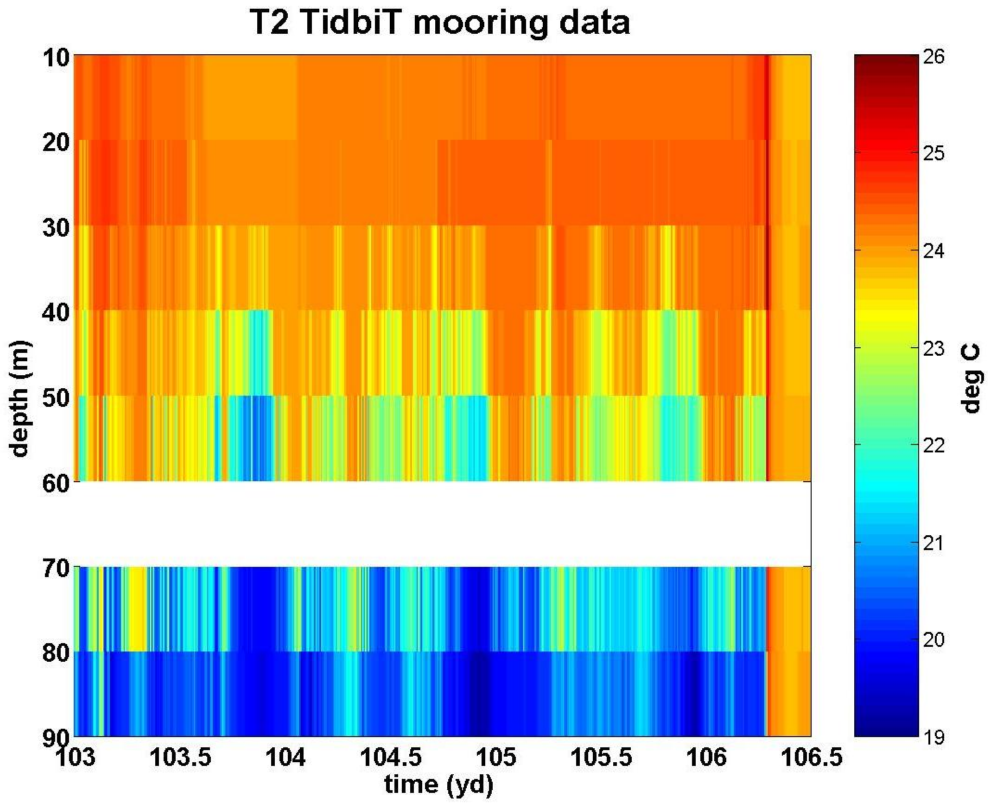


Figure 19. TidbiT temperature data from the T2 mooring location in 95m of water (along the acoustic transmission path).

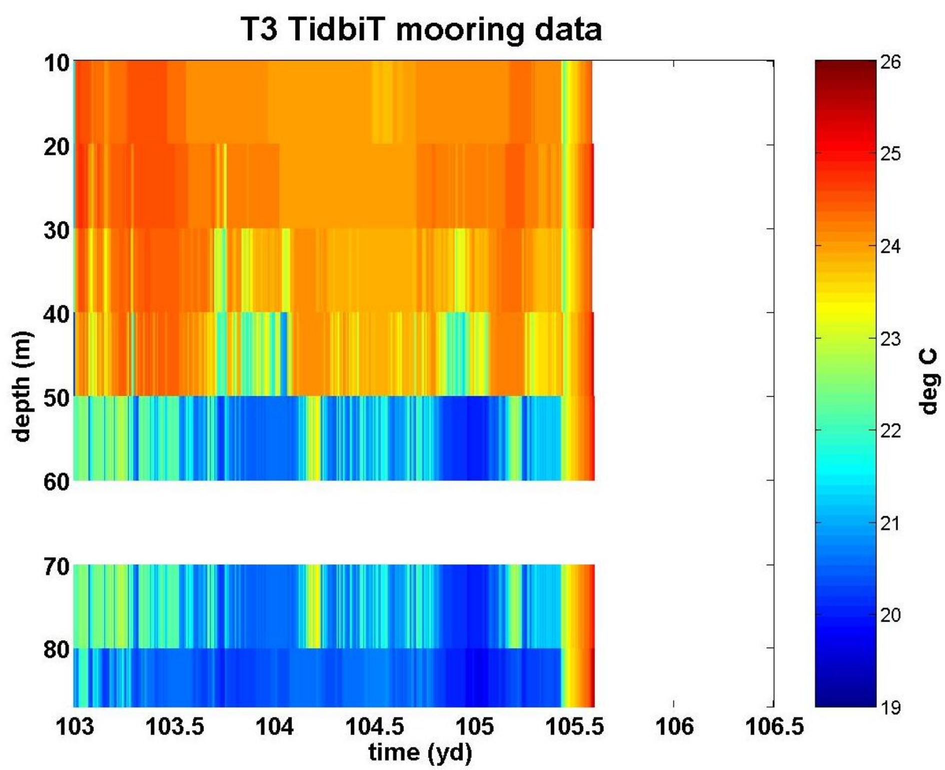


Figure 20. TidbiT temperature data from the T3 mooring location in 90m water depth (along the acoustic transmission path).

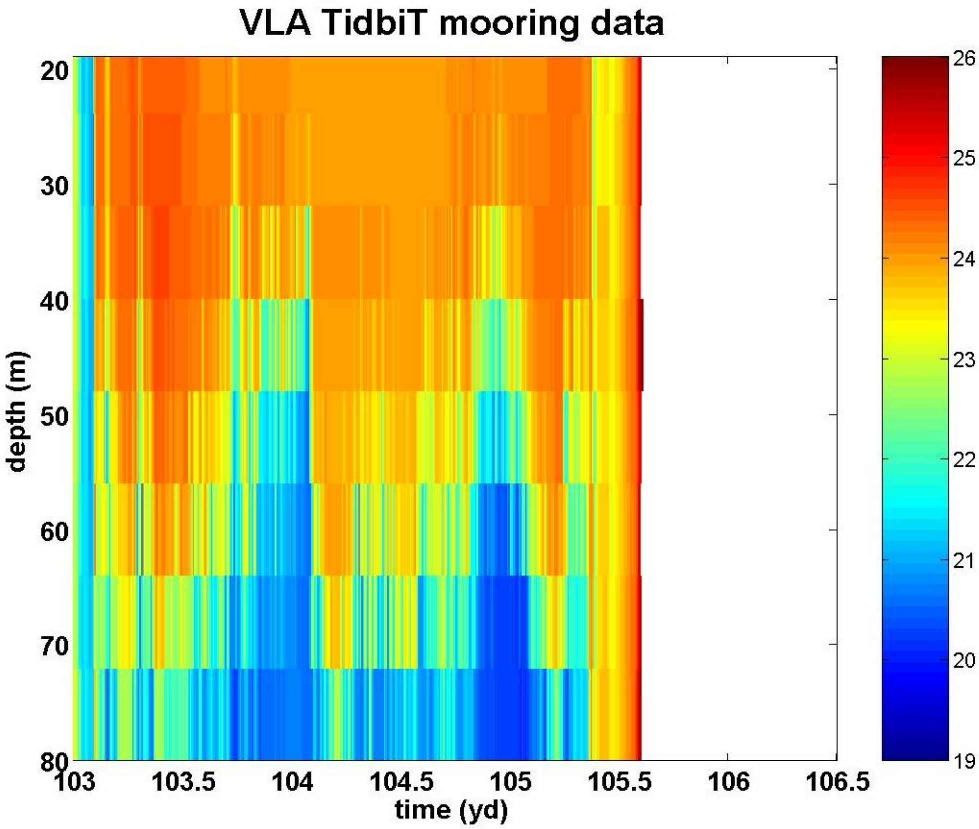


Figure 21. TidbiT temperature data from the VLA mooring locations. The TidbiT sensors were collocated with the hydrophones (8m spacing), with an additional sensor mounted on the interrogator housing above the data acquisition system.

4.0 Basin Experiment (April 2005)

4.1 NPS 400 Hz SYS11 sound source (B1 mooring)

The sound sources used during the basin acoustic transmissions were 400 Hz sources manufactured by Webb Research Corporation (WRC) belonging to NPS. Each source was deployed with a short 6-m hydrophone array and onboard 2-channel receiver to operate in a 'transceiver' mode. This source has 100 Hz bandwidth, and transmits a 5.11 second, 511 digit pseudo-random (m-sequence) signal at 183 dB//1µPa @ 1m. The 6m hydrophone array is connected to a dual-channel receiver, with each channel parallel-wired to 4 hydrophones. The receiver system was built to resolve the difference between the positive and negative going arrivals (up/down beamforming), rather than multi-channel data collection. During each reception the data is demodulated and coherent averaged. Only the base-band, averaged information for each channel is saved internally by the source, with no time series saved.

The planned distance between the B1 and B2 moorings is 167.2 km, which corresponds to an

acoustic travel time of 111.46 s for signal propagation. This distance was used to set the reception time for the on-board data collection start time of 114s after signal transmission (one sequence into the received signal).

To acoustically sample the internal waves in the basin a transmission period of 5-10 minutes was desired. Hardware limitations of the sound source prevented both long transmission times, as well as long reception times (from the alternate source), given the travel time delays required for signal propagation. Given these constraints, and the uncertainty of the mooring distances prior to deployment, the transmission period was set to 15 minutes. The total power available in the battery pack limited the transmission length to 9 sequences (45.99 seconds).

The sound source timing uses a modified Astronomical Day, which will not be explained further in this document. The conversion from Astronomical Day to standard Year Day is done by subtracting 3370 from the Astronomical Day number (ie, Day 3487 = YD 117 = April 27th, 2005).

Table 14. April-July 2005 'B1' deployment information (SYS11)

Deployed (date/time UTC)	28 April 2005, 04:47
Latitude N (anchor drop)	21° 21.7977'
Longitude E (anchor drop)	118° 35.5362'
Water depth (anchor drop)	2483 m
Latitude N (surveyed)	21 21.8661' N
Longitude E (surveyed)	118 35.6276' E
Water depth (surveyed)	2480 m
Source depth	806 m

Table 15. April-July 2005 'B1' source time checks (clock #CK64).

System time (UTC) DDDD HH MM SS	SAIL clock time (UTC) DDDD HH MM SS.SSSSSS
3487 15:04:47	3487 15:04:47.000080
3487 15:13:33	3487 15:13:33.000092
Average Δt at deployment	+0.000086 (source timing fast)
3577 13:47:22	3577 13:47:22.031647
3577 13:48:25	3577 13:48:25.031648
3577 13:50:42	3577 13:50:42.031649
Average Δt at recovery	+0.031648 (source timing fast)
Drift rate	**+350.9222 µsec/day (fast)**

Table 16. NPS 400 Hz 'B1' source transmission schedule.

Start time (UTC)	3488 05:00:00 (4/28/05 13:00 local)
Stop time (UTC)	3572 23:50:00 (7/22/05 07:50 local)
Transmission times (minutes after the hour)	0, 15, 30, 45
Center frequency (Hz)	400
Bandwidth (Hz)	100
Source level	183 dB re 1 μPa @ 1m
Cycles per digit	4
Digit width	10 ms
Digits per sequence (sequence length)	511 (5.11 s)
Number of sequences transmitted	9 (45.99 s)
m-sequence LAW (octal)	1533
Sequence initialization	000000001
Phase modulation angle	87.46035°
Reception times (minutes after hour)	6.9, 21.9, 36.9, 51.9
Number of sequences received/averaged	8

Acoustic triangulation was used to measure the mooring motion of the tomography source. The same interrogator/transponder equipment described in section 3.5 for the VLA mooring was used. The interrogator was deployed at ~775m depth, 20m above the tomography source hydrophone array, and 1m below the 64" sphere.

Table 17. 'B1' Interrogator settings

Serial number/address	#I2
Transmitting frequency	10.5 kHz
Receiving frequencies	11.5, 12.0, 12.5 kHz
Interrogation interval	20 minutes
Start time	YD 117 12:50:00

Table 18. Benthos XT-6001 transponder deployment information

Transponder serial number	#73604	#73607	#73602
Receive frequency (kHz)	10.5	10.5	10.5
Transmit frequency (kHz)	11.5	12.0	12.5
Deployed (date/time UTC)	4/28/05 06:25	4/28/05 06:48	4/28/05 07:04
Latitude N (anchor drop)	21° 21.3088' N	21° 21.4947' N	21° 23.2456' N
Longitude E (anchor drop)	118° 37.0408E	118° 34.4094' E	118° 35.6400' E
Water depth (m)	2495 m	2472 m	2468 m
Latitude N (surveyed)	**21° 21.3053' N**	**21° 21.4725' N**	**21° 23.2392' N**
Longitude E (surveyed)	**118° 37.165' E**	**118° 34.5562' E**	**118° 35.7885' E**
Distance from anchor drop	2.8498 km	1.9878 km	1.1945 km

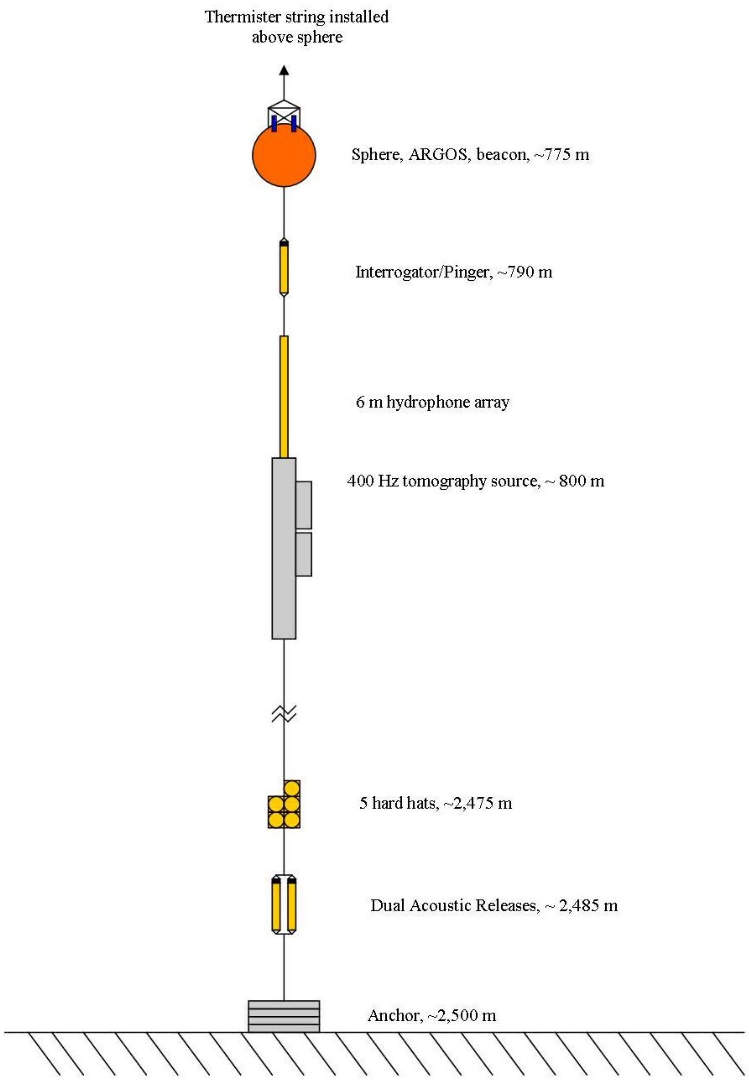


Figure 22. Initial design for the acoustics (lower) section of the B1 mooring.

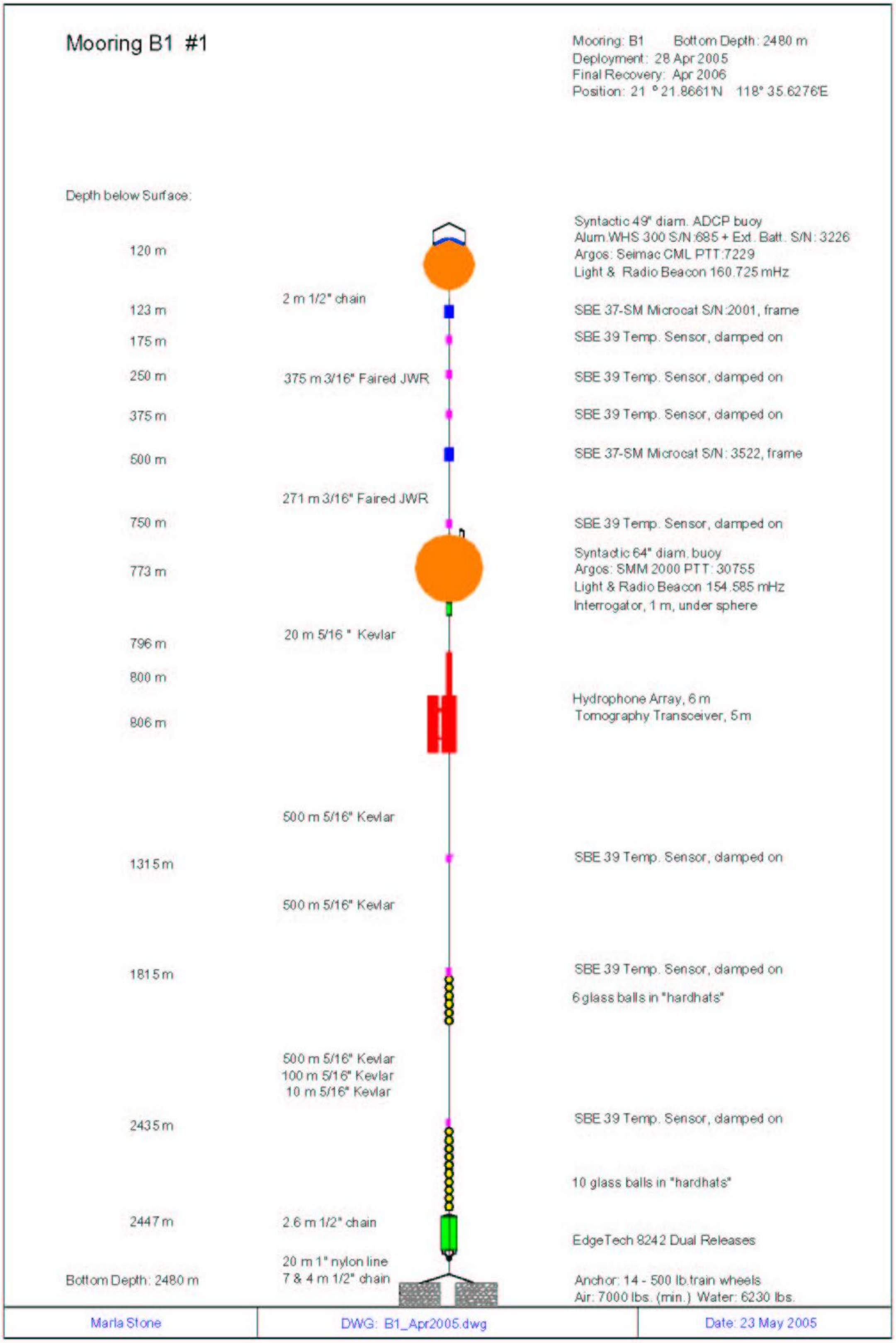


Figure 23. B1 mooring design, as deployed 28 April 2005.

4.2 NPS 400 Hz SYS13 sound source (B2 mooring)

A 400 Hz WRC organ pipe transceiver, equivalent to the ‘B1’ mooring of section 4.1, was moored at the ‘B2’ location. It transmitted 400 Hz, phase encoded signal every 15 minutes, starting at 5 minutes after the hour, and received signals from the ‘B1’ mooring with its 2 channel receiver system. The other instruments and mooring design for the B2 mooring were contributed by the National Taiwan University.

Table 19. April-July 2005 'B2' deployment information (SYS13)

Deployed (date/time UTC)	4/26/05 19:48
Latitude N (anchor drop)	21° 56.0279’ N
Longitude E (anchor drop)	120° 08.4244’ E
Water depth (m)	3362 m
Latitude N (surveyed)	20° 55.8843’ N
Longitude E (surveyed)	120° 08.33097’ E
Water depth (surveyed)	3354 m
Source depth (m)	856.5 m

Table 20. April-July 2005 'B2' source time checks (clock #CK66)

System time (UTC) DDDD HH MM SS	GPS SAIL time (UTC) DDDD HH MM SS.SSSSSS
3486 05:15:51	3486 05:15:51.000024
Average Δt at deployment	-0.000024 (source timing slow)
3576 02:35:47	3576 02:36:39.367874
3576 02:38:21	3576 02:39:13.367870
3576 02:39:10	3576 02:40:02.367869
Average Δt at recovery	-0.367871 (source timing slow)
Drift rate	**-4092.2156 μsec/day (retarding)**

Table 21. NPS 400 Hz 'B2' source transmission schedule (April – July 2005).

Start time (UTC)	3486 18:00:00
Stop time (UTC)	3572 23:50:00 (7/22/05 07:50 local)
Transmission times (minutes after the hour)	5, 20, 35, 50
Center frequency (Hz)	400
Bandwidth (Hz)	100
Source level	180 dB re 1 μPa @ 1m
Cycles per digit	4

Digit width	10 ms
Digits per sequence (sequence length)	511 (5.11 s)
Number of sequences transmitted	9 (45.99 s)
m-sequence LAW (octal)	1473
Sequence initialization	000000001
Phase modulation angle	87.46035°
Reception times (minutes after the hour)	1.9, 16.9, 31.9, 46.9
Number of sequences received/averaged	8

Acoustic triangulation was used to measure the mooring motion of the tomography source. The same interrogator/transponder equipment described in section 3.5 for the VLA mooring was used. The interrogator target depth was 801.5m, 20 m above the tomography source hydrophone array, directly below the 64" sphere. The transponder survey for B2 was not optimal, as there was no survey position near the mooring (only a large outer circle). Additional survey work in July 2006 is recommended prior to processing the B2 mooring motion.

Table 22. Interrogator settings for B2 mooring.

Serial number/address	#I10
Transmitting frequency	10 kHz
Receiving frequencies	11.5, 12.0, 12.5 kHz
Interrogate interval	20 minutes
Start time (UTC)	26 April 2005, 06:00

Table 23. Pre-deployment time check for #I10 interrogator (B2 mooring, April 2005)

System time (UTC) DDD HH MM SS	GPS SAIL time (UTC) DDDD HH MM SS.SSSSSS
116 03:21:00	3486 03:20:59.910174
116 03:26:00	3486 03:25:59.904882

Table 24. Benthos XT-6001 transponder deployment information.

Transponder serial number	#73596	#73598	#73594
Receive frequency (kHz)	10.0	10.0	10.0
Transmit frequency (kHz)	11.5	12.0	12.5
Deployed (date/time UTC)	4/26/05 21:30	4/26/05 21:50	4/26/05 22:12
Latitude N (anchor drop)	20° 57.6644' N	20° 55.1345' N	20° 55.0689' N
Longitude E (anchor drop)	120° 8.2423' E	120° 9.7328' E	120° 6.3088' E
Water depth (m)	3370 m	3377 m	3203 m
Latitude N (surveyed*)	20° 57.683' N	20° 55.193' N	20° 55.02' N
Longitude E (surveyed*)	120° 8.094' E	120° 9.487' E	120° 6.605' E

* - recommend additional survey before these locations are used for mooring motion correction.

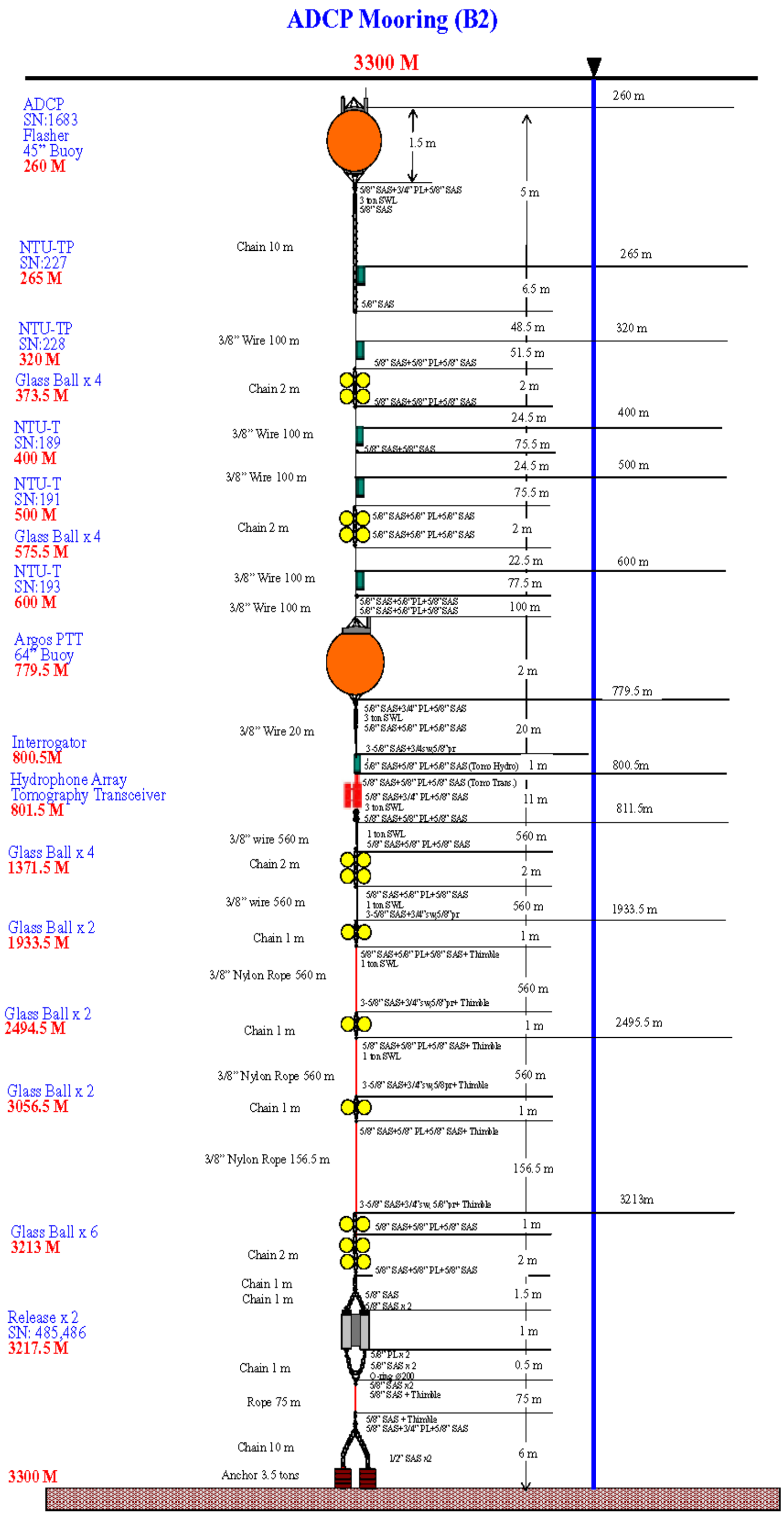


Figure 24. B2 mooring 'as deployed' for April 2005. Mooring design by National Taiwan University

4.3 Luzzon Straight Physical Oceanography (L1 mooring)

Table 25. L1 Mooring Information - April 2005

Deployed (date/time UTC)	25 April 2005,
Latitude N (anchor drop)	20° 35.3847’ N
Longitude E (anchor drop)	121° 55.1166’ E
Water depth (anchor drop)	447 m

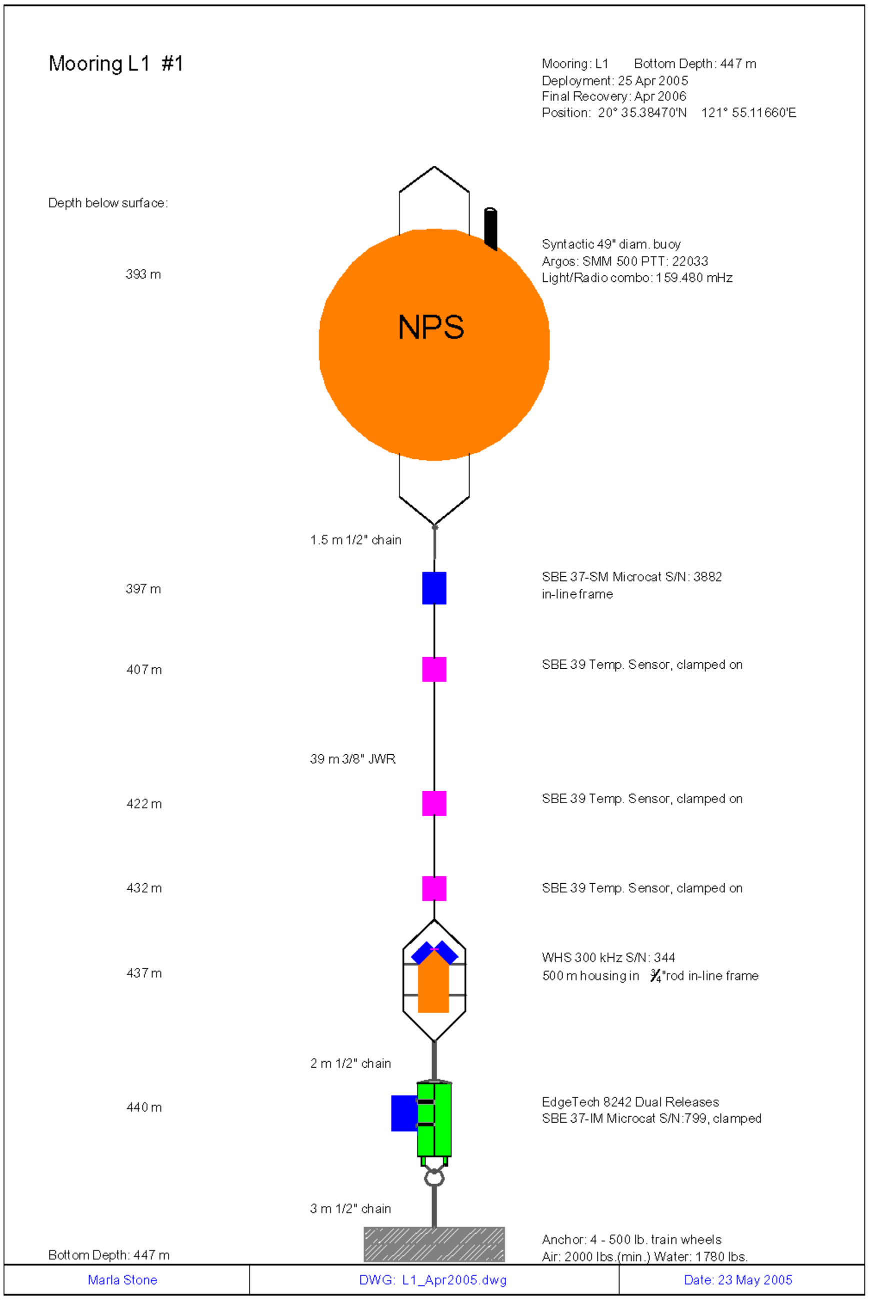


Figure 25. Luzon straight mooring drawing, as deployed April 25, 2005.

4.4 ADCP mooring (S7 mooring)

Table 26. S7 ADCP mooring information - April 2005.

Deployed (date/time UTC)	29 April 2005
Latitude N (anchor drop)	21° 36.8363’
Longitude E (anchor drop)	117° 16.9854’
Water depth (anchor drop)	353 m

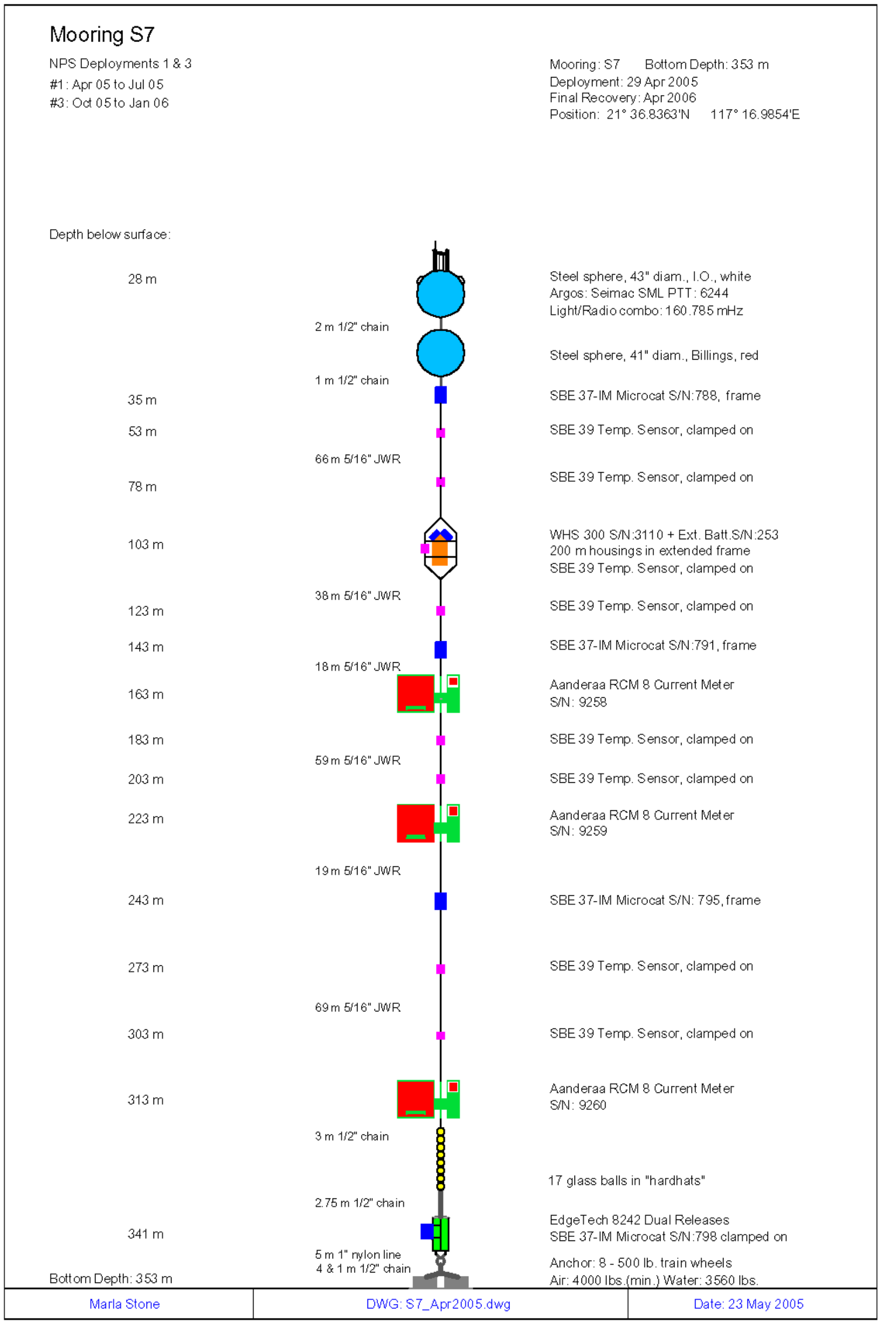


Figure 26. ADCP mooring S7 (as deployed), April 29, 2005. (NPS)

4.5 Sonobuoy Transect

Expired Navy SSQ-57B omni-directional sonobuoys were deployed along the B1 - B2 transmission path to provide validation data for the source operation, and in-situ Transmission Loss (TL) measurements along the path. Sonobuoy depth setting was 400 feet. Several 57B GPS buoys were used (sampled at 80kHz), that had additional sensor settings of CO and an automatic gain control setting of A1.

Table 27. Sonobuoy TL drop locations during April 27-29, 2005.

DATE	TIME local time = UTC+8	Latitude (N)	Longitude (E)	Comments
4/27/05	0935 L	21 00.1616' N	120 01.6031'	B2 transmissions at 0950L, wise.daq files
	1314 L	21 05.1212'	119 49.8228'	1hr, 400' depth. lost signal at 1327L
	1406 L	21 08.1171'	119 39.5429'	3hr, 400' depth
	1658 L	21 09.81'	119 32.8'	1hr, 400' depth
	1730 L	21 10.9176'	119 27.1580'	
	1803 L	21 12.26'	119 21.28'	
	1832 L	21 13.4911'	119 15.63'	
	1912 L	21 15.0618'	119 08.2582'	3hr, 400' depth
	2151 L	21 16.30'	119 00.09'	1hr, 400' depth, collecting to wise_k.daq files
	2236 L	21 18.1468'	118 51.1610'	Wise_L.daq files
4/28/05	1247 L	21 22.2182'	118 36.3'	At B1 mooring. Wise_N.daq files. Phone did not deploy from launch container (tangled at surface)
	1900 L	21 24.0476'	118 26.2298'	Ship's speed 10.5 kts. Wise_P.daq files
	1945 L	21 25.9124'	118 18.2005'	Regular LF explosions/drum beats heard ~20s period
	2259 L	21 28.95'	118 03.37'	1 hr, 400' depth
	2356 L	21 31.52'	117 52.75'	1 hr, 400' depth
4/29/05	0027 L	21 32.83'	117 47.0555'	
	0159 L	21 34.9'	117 37.74'	
	0234 L	21 36.266'	117 31.298'	
	0341 L	?? not logged	??	At S7 during CTD. J9 & GPS buoy in water 8hr setting

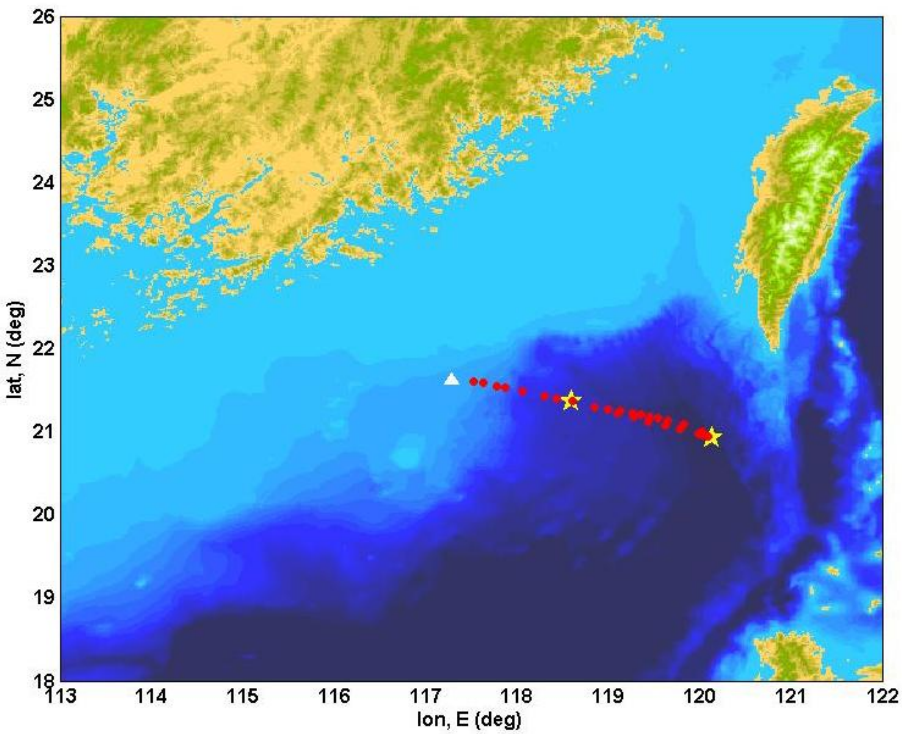


Figure 27. Windy Island Soliton Basin experiment locations. Primary source/receiver locations (B1 & B2) are noted by the yellow stars, sonobuoy drop locations are shown as red circles, and the shallow water ADCP as the white triangle.

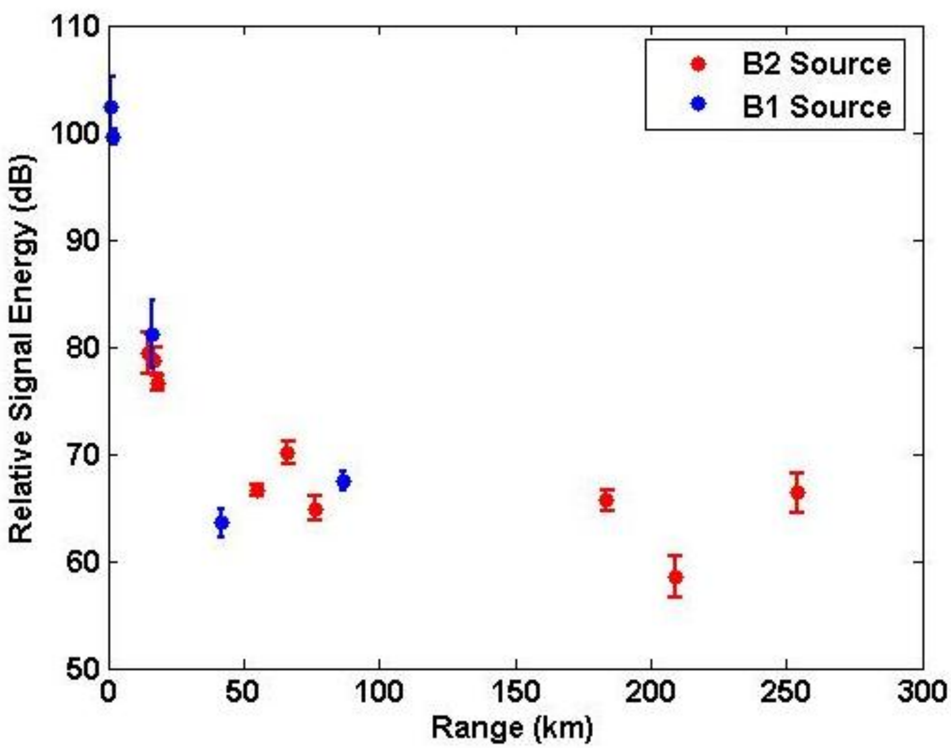


Figure 28. Relative transmission loss (TL) as a function of range. Estimates based on data from April 2005 sonobuoy receptions.

5.0 Basin Experiment (July 2005)

5.1 NPS 400 Hz SYS11 sound source (B1 mooring)

The first turn-around cruise to recover, re-battery, and re-deploy the acoustic moorings was conducted July 24-31, 2005. The B1 mooring recovery began at 08:20 GMT with the release of the anchor at 21 21.5704'N, 118 35.3489' E, and acoustic releases on deck by 09:29. By 10:22 the sound source (SYS11) was on deck, and downloading of data for all instruments was underway by 12:30.

The sound source was refurbished and resealed by 21:00, and ready for deployment (purged and reprogrammed) by 23:00 (07:00 local). The B1 mooring was redeployed between 05:00 and 11:15 GMT. Upon review of the downloaded receiver data, it was evident that a problem existed with the sound source receiver. The receiver data and status files had started collection on day 3488 05:00 (as programmed, 28 April 13:00 local), but stopped unexpectedly after the 3497 22:00 transmission (May 7th) after only 9 days of operation.

Table 28. NPS 400 Hz source 'B1' July deployment information (SYS11)

Deployed (date/time UTC)	27 July 2005, 11:15
Latitude N (anchor drop)	21° 21.9385'
Longitude E (anchor drop)	118° 35.5725'
Water depth (anchor drop)	2480 m
Latitude N (surveyed)	21 21.8841' N
Longitude E (surveyed)	118 35.4413' E
Water depth (surveyed)	2482 m
Source depth	821 m

Table 29. July-October 2005 'B1' source deployment time checks (clock #CK64).

System time (UTC) DDDD HH MM SS	SAIL clock time (UTC) DDDD HH MM SS.SSSSSS
3577 21:18:11	3577 21:18:11.032030
3577 21:19:50	3577 21:19:50.032030
3577 21:21:38	3577 21:21:38.032034
3577 21:22:13	3577 21:22:13.032032
Average Δt at deployment	-0.0320315 (source timing slow)
3679 00:58:46	3679 00:58:45.993371
3679 00:58:54	3679 00:58:53.993369
3679 00:59:03	3679 00:59:02.993371
Average Δt at recovery	+0.006629 (source timing fast)
Drift rate	**+382.2074 μsec/day (advancing)**

Figure 29. 400 Hz Tomography source ready for deployment at the B1 mooring site.

Table 30. NPS 400 Hz 'B1' reception schedule.

Start time (UTC)	3578 10:00:00 (7/27/05 18:00 local)
Stop time (UTC)	3667 23:50:00 (10/25/05 07:50 local)
Transmission times (minutes after the hour)	0, 15, 30, 45
Reception times (minutes after hour)	6.5833, 21.5833, 36.5833, 51.5833
Number of sequences received/averaged	8

Table 31. July-October Mooring Motion timing checks (Interrogator #I2)

Interrogator time (UTC) DDD HH:MM:SS	SAIL clock time (UTC) DDDD HH:MM:SS.SSSSSS
207 16:14:00	3577 13:13:59.756914
207 16:16:00	3577 13:15:59.754683
207 16:17:00	3577 13:16:59.754683
Average Δt at deployment	+0.2445733 s (interrogator is fast)
308 16:24:00	3678 16:23:03.825422
308 16:25:00	3678 16:24:03.824264
308 16:27:00	3678 16:26:03.822164
Average Δt at recovery	+56.17605 s (interrogator time is fast)
Drift rate	**553.058 msec/day (system time advancing)**

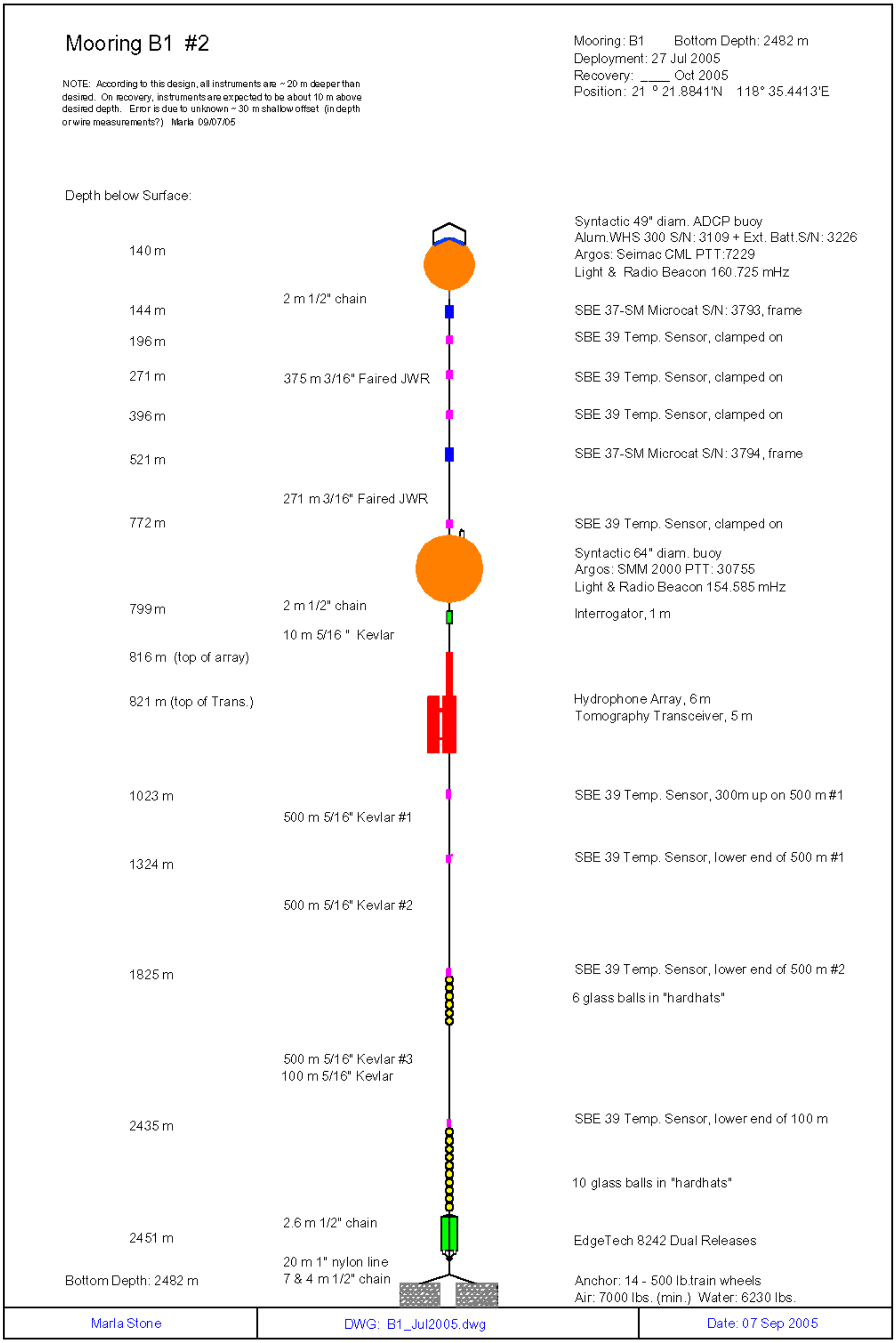


Figure 30. B1 mooring design "as deployed" July 27, 2005.

5.2 NPS 400 Hz SYS13 sound source (B2 mooring)

The B2 mooring turn-around was conducted on July 25, 2005. The acoustic releases were fired at 24 July, 21:15 GMT (25 July, 05:15L) and the recovery effort began. The sound source was on deck by 00:45 GMT. By 11:30L, the deck was cleared and the sound source turn-around was performed in calm seas until 20:00 local time when deck preparations began for re-deployment of the B2 mooring.

The B2 mooring was deployed with the acoustic release ~106m above the bottom. This deployment configuration had the source position 5-10m lower than during the April-July deployment.

The acoustic interrogator #I10 suffered a catastrophic leak during the April-July 2005. The housing was off-gassing after recovery, and the electronics could not be removed from the pressure hull. The transducer was removed (using extreme force) when it was evident that leakage occurred, causing the transducer to break free of the electronics support frame. The battery packs had expanded with the corrosion, and have caused the entire electronics assembly to remain lodged in the pressure hull. Due to this problem, the B2 mooring was deployed without a means to acoustically measure mooring motion.

Upon review of the downloaded receiver data, it was evident that a problem existed with the sound source receiver. The receiver data and status files had started collection on day 3488 05:00 (as programmed, 28 April 13:00 local), but stopped unexpectedly after the reception of the 3487 21:15 transmission from the B1 source, after 1.1 days of operation. The receiver data collected over the first day's operation only contained zeros, suggesting a bad electrical connection to the hydrophone array.

Table 32. July-October 2005 'B2' deployment information (SYS13)

Deployed (date/time UTC)	7/25/05 16:59
Latitude N (anchor drop)	20° 56.1757' N
Longitude E (anchor drop)	120° 08.2558' E
Water depth (m)	3353 m
Latitude N (surveyed)	20° 56.0525' N
Longitude E (surveyed)	120° 08.2795' E
Water depth (surveyed)	3353 m
Source depth (m)	801.5 m

Table 33. July 'B2' time check (clock #CK66)

System time (UTC) DDD HH MM SS	GPS SAIL time (UTC) DDD HH MM SS.SSSSSS
3576 11:44:07	3576 11:44:59.370469
3576 11:47:01	3576 11:47:53.370479
Average Δt at deployment	-52.370479 s (source time slow)

Table 34. July - October 2005 'B2' source transmission schedule (SYS13).

Start time (UTC)	3576 18:00:00 (7/25/05 - YD 206)
Stop time (UTC)	3667 23:50:00 (10/24/05 - YD 297)
Transmission times (minutes after the hour)	5, 20, 35, 50
Center frequency (Hz)	400
Bandwidth (Hz)	100
Source level	180 dB re 1 μPa @ 1m
Cycles per digit	4
Digit width	10 ms
Digits per sequence (sequence length)	511 (5.11 s)
Number of sequences transmitted	9 (45.99 s)
m-sequence LAW (octal)	1473
Sequence initialization	000000001
Phase modulation angle	87.46035°
Reception times (minutes after the hour)	1.9, 16.9, 31.9, 46.9
Number of sequences received/averaged	8

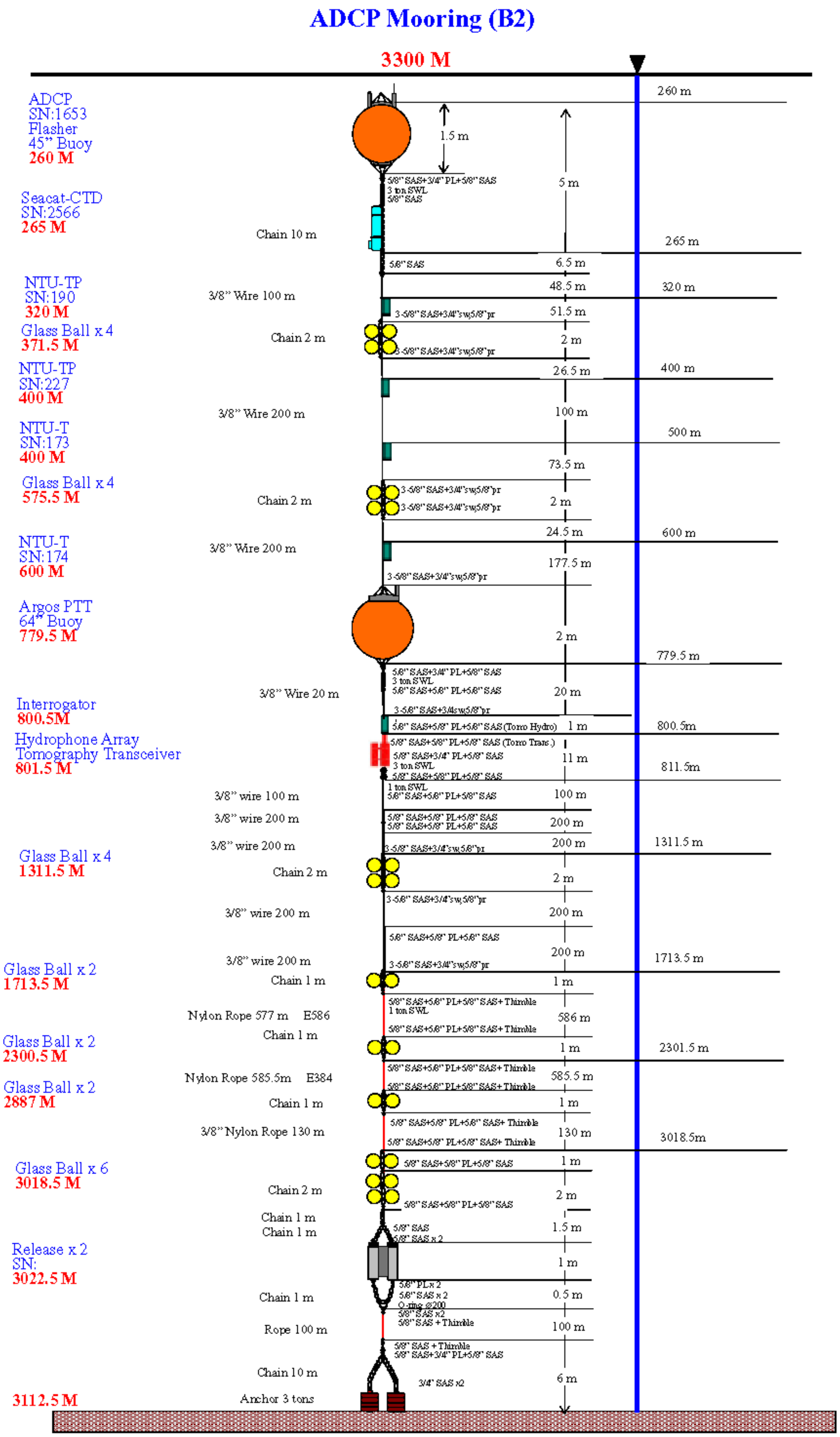


Figure 31. B2 mooring configuration for July 2005 deployment (NTU).

6.0 Basin Experiment Cruise (27 Oct - 6 Nov 2005)

The second turn-around cruise to recover, re-battery, and re-deploy the acoustic moorings was conducted October 27 - November 6, 2005.

6.1 November 2005 B1 mooring recovery (SYS11 source)

The B1 mooring recovery began 3 November at 22:35 GMT with the release of the anchor, and acoustic releases on deck by 23:37. By 00:50 the sound source (SYS11) was on deck, and downloading of data for all instruments was underway by 05:00 on November 4.

Upon review of the downloaded receiver data, it was evident that the problem with the sound source receiver continued into the 2nd deployment cruise, however this time the receiver operated for 53 days before it stopped collecting data. The receiver data and status files had started collecting data with the B2 transmission on day 3578 10:05 as programmed (July 27, 18:00 local), but stopped unexpectedly after the reception of the day 3631 04:20 (September 18) transmission after 53 days of operation. An incomplete status record was also recorded to disk on day 3678 12:46 (November 4th), but it is unclear what the source was doing once the receive records stopped. Due to the problems experienced with the 400 Hz source receivers, Scripps Institution of Oceanography was approached to borrow two Simple Tomographic Acoustic Receiver (STAR) systems for deployment on the B1 mooring. See section 6.4 for additional details about these systems.

6.2 November 2005 B1 mooring deployment (STAR receiver)

Due to the loss of source SYS13 during the recovery of B2, SYS11 was deployed on the B2 mooring, and the B1 mooring was deployed with a STAR receiver only.

Table 35. 'B1' November 2005 – February 2006 deployment information

Deployed (date/time UTC)	4 November 2005, 18:13
Latitude N (anchor drop)	21° 21.151’
Longitude E (anchor drop)	118° 34.871’
Water depth (anchor drop)	2484 m
Latitude N (surveyed)	21 21.1112’ N
Longitude E (surveyed)	118 34.7456’ E
STAR S/N 10 depth (m)	911 m
Receiver depths (m)	877, 886, 895, & 904

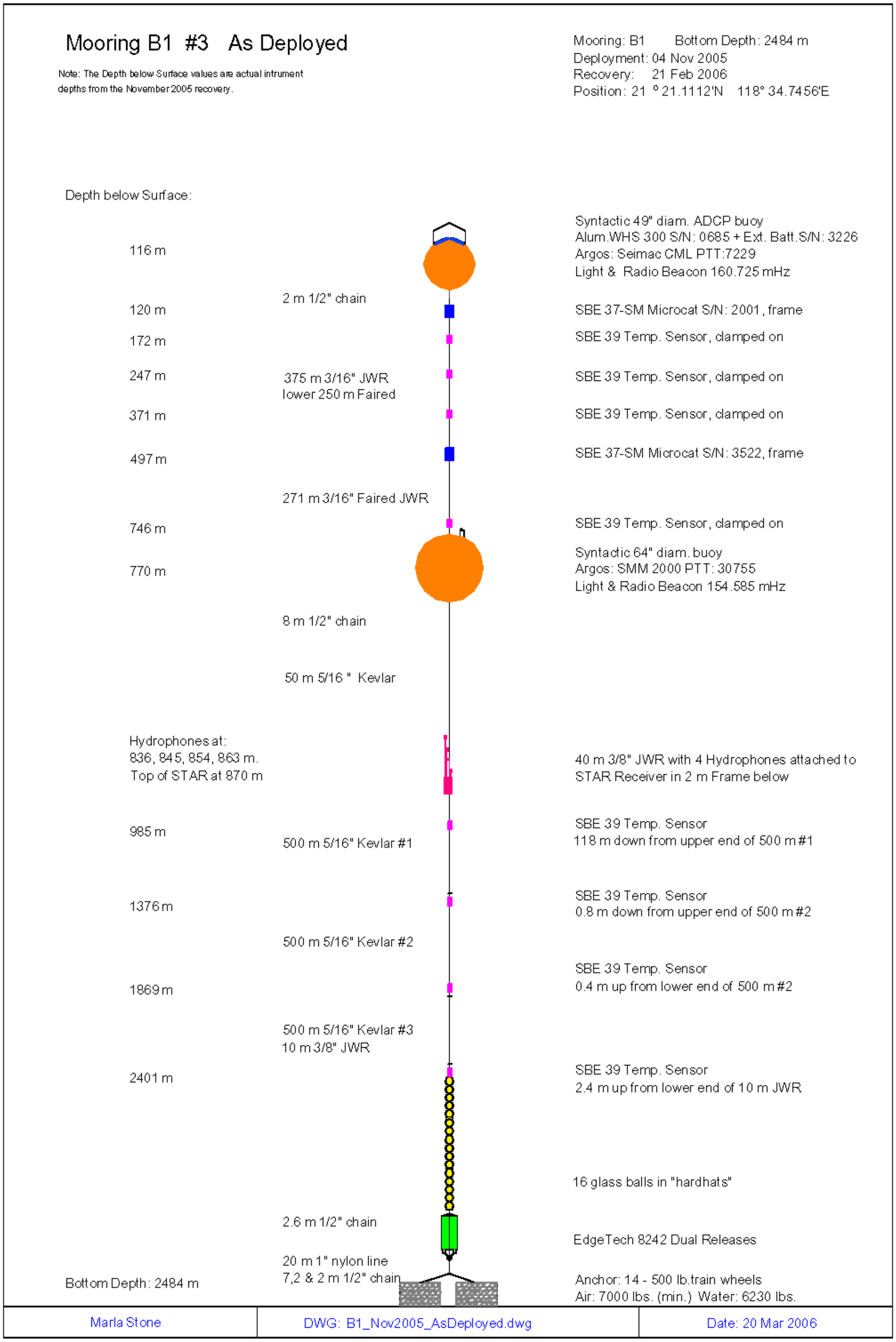

Mooring B1 #3 As Deployed
Note: The Depth below Surface values are actual intrument depths from the November 2005 recovery.
Mooring: B1 Bottom Depth: 2484 m
Deployment: 04 Nov 2005
Recovery: 21 Feb 2006
Position: 21 ° 21.1112'N 118° 34.7456'E
Depth below Surface:
116 m
Syntactic 49" diam. ADCP buoy
Alum.WHS 300 S/N: 0685 + Ext. Batt.S/N: 3226
Argos: Seimac CML PTT:7229
Light & Radio Beacon 160.725 mHz
2 m 1/2" chain
120 m
SBE 37-SM Microcat S/N: 2001, frame
172 m
SBE 39 Temp. Sensor, clamped on
247 m
375 m 3/16" JWR
lower 250 m Faired
SBE 39 Temp. Sensor, clamped on
371 m
SBE 39 Temp. Sensor, clamped on
497 m
SBE 37-SM Microcat S/N: 3522, frame
271 m 3/16" Faired JWR
746 m
SBE 39 Temp. Sensor, clamped on
770 m
Syntactic 64" diam. buoy
Argos: SMM 2000 PTT: 30755
Light & Radio Beacon 154.585 mHz
8 m 1/2" chain
50 m 5/16 " Kevlar
Hydrophones at:
836, 845, 854, 863 m.
Top of STAR at 870 m
40 m 3/8" JWR with 4 Hydrophones attached to
STAR Receiver in 2 m Frame below
985 m
500 m 5/16" Kevlar #1
SBE 39 Temp. Sensor
118 m down from upper end of 500 m #1
1376 m
SBE 39 Temp. Sensor
0.8 m down from upper end of 500 m #2
500 m 5/16" Kevlar #2
1869 m
SBE 39 Temp. Sensor
0.4 m up from lower end of 500 m #2
500 m 5/16" Kevlar #3
10 m 3/8" JWR
2401 m
SBE 39 Temp. Sensor
2.4 m up from lower end of 10 m JWR
16 glass balls in "hardhats"
2.6 m 1/2" chain
EdgeTech 8242 Dual Releases
20 m 1" nylon line
7,2 & 2 m 1/2" chain
Bottom Depth: 2484 m
Anchor: 14 - 500 lb.train wheels
Air: 7000 lbs. (min.) Water: 6230 lbs.
Marla Stone
DWG: B1_Nov2005_AsDeployed.dwg
Date: 20 Mar 2006

Figure 32. B1 mooring design, as deployed November 4, 2005.

6.3 October 2005 B2 mooring recovery (SYS13 source)

The B2 mooring was recovered on October 29, 2005. The acoustic releases were fired at 08:00 GMT (16:00L) and the recovery effort began. During the recovery effort the Taiwanese jacketed wire rope (JWR) was coming aboard severely twisted once the tension of the mooring was released. After recovering the acoustic releases and several lengths of twisted JWR and 12 hardhat assemblies, the JWR broke roughly 1500m from the acoustic releases (below the sound source). Mooring recovery resumed from the top sphere, but the JWR broke again above the 64" tomography sphere. Mooring recovery once again resumed from the 64" tomography sphere, however the JWR nicopress fitting pulled loose above the 6-m tomography hydrophone array (Figure 33), letting the SYS13 tomography source (still connected to 300 m of JWR and 4 hardhats) sink to the bottom. SYS13 is lost at sea in 3112 m of water.

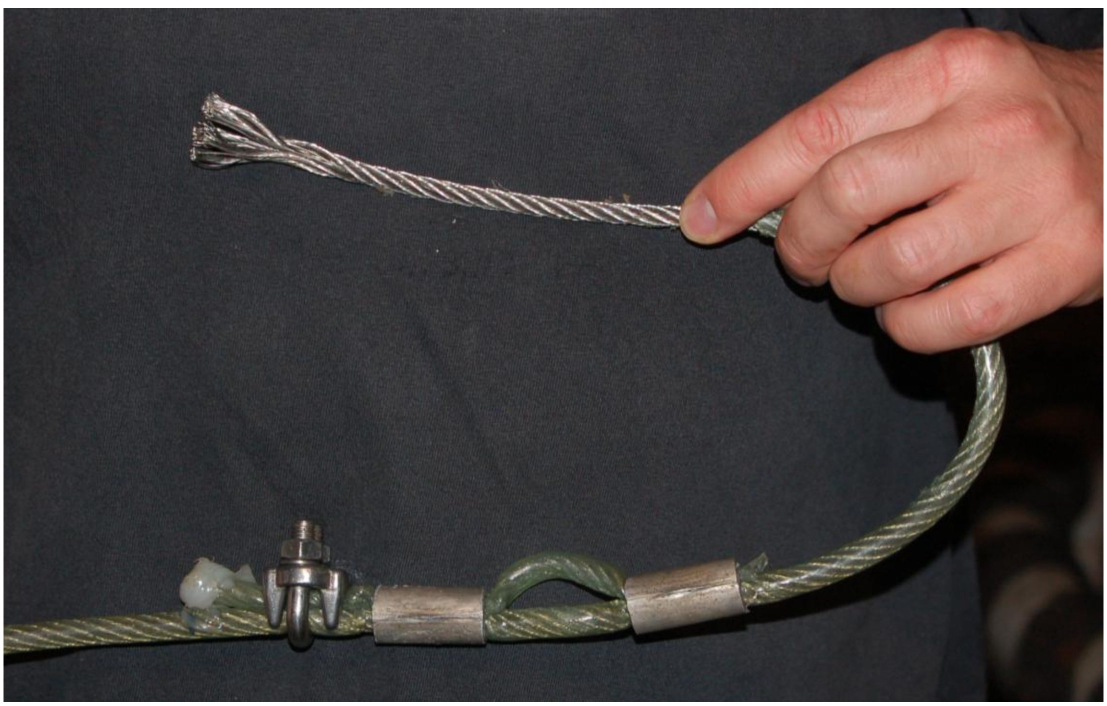


Figure 33. Jacketed wire-rope failure, causing the loss of sound source SYS13 during the October recovery effort of the B2 mooring.

6.4 November 2005 B2 mooring deployment (SYS11 source)

The sound source SYS11 was redeployed on the B2 mooring between 08:01 and 11:20 GMT on 5 November, 2005.

Table 36. November 2005 – February 2006 'B2' deployment information (SYS11)

Deployed (date/time UTC)	11/05/05 11:18
Latitude N (anchor drop)	20° 56.134' N
Longitude E (anchor drop)	120° 08.102' E
Water depth (m)	3348 m
Latitude N (surveyed)	20° 56.0971' N
Longitude E (surveyed)	120° 07.8449' E
Target source depth	802 m
Actual source depth	720-727 m (based on SB39 pressure sensor data)
STAR electronics depth (m)	877 m
STAR receiver depths (m)	845, 854, 863, 872

Table 37. NPS 400 Hz 'B2' timing checks (#CK64)

System time (UTC) DDDD HH MM SS	GPS SAIL time (UTC) DDDD HH MM SS.SSSSSS
3679 00:58:46	3679 00:58:45.993371
3679 00:58:54	3679 00:58:53.993369
3679 00:59:03	3679 00:59:02.993371
Average Δt at deployment	+0.0066296s (source timing fast)
3788 14:15:40	3788 14:15:38.918485
3788 14:16:06	3788 14:16:04.918486
3788 14:17:48	3788 14:17:46.918486
Average Δt at recovery	+1.0815143s (source timing fast)
Drift rate	**+9811.532 μsec/day (advancing)**

Table 38. November 2005 - January 2006 'B2' source transmission schedule (SYS11).

Start time (UTC)	3679 15:50:00 (11/05/05 - YD 309)
Stop time (UTC)	3755 00:00:00 (1/20/06 - YD 20)
Transmission times (min. after the hour)	05, 20, 35, 50

Center frequency (Hz)	400
Bandwidth (Hz)	100
Source level	180 dB re 1 μPa @ 1m
Cycles per digit	4
Digit width	10 ms
Digits per sequence (sequence length)	511 (5.11 s)
Number of sequences transmitted	9 (45.99 s)
m-sequence LAW (octal)	1021
Sequence initialization	000000001
Phase modulation angle	87.46035°

The B2 source was initially deployed with the intention of broadcasting at 00, 15, 30, and 45 minutes after the hour, which correspond to the reception times of the B1 STAR receiver. Unfortunately, a programming error at deployment set the source broadcasts 5 minutes fast (table 37), missing the B1 reception windows. The B2 STAR receiver (source mooring) was programmed to record ambient noise at 5, 20, 35, and 50 minutes after the hour, so the B2 STAR receiver actually contains reverberation data during the November – January deployment.

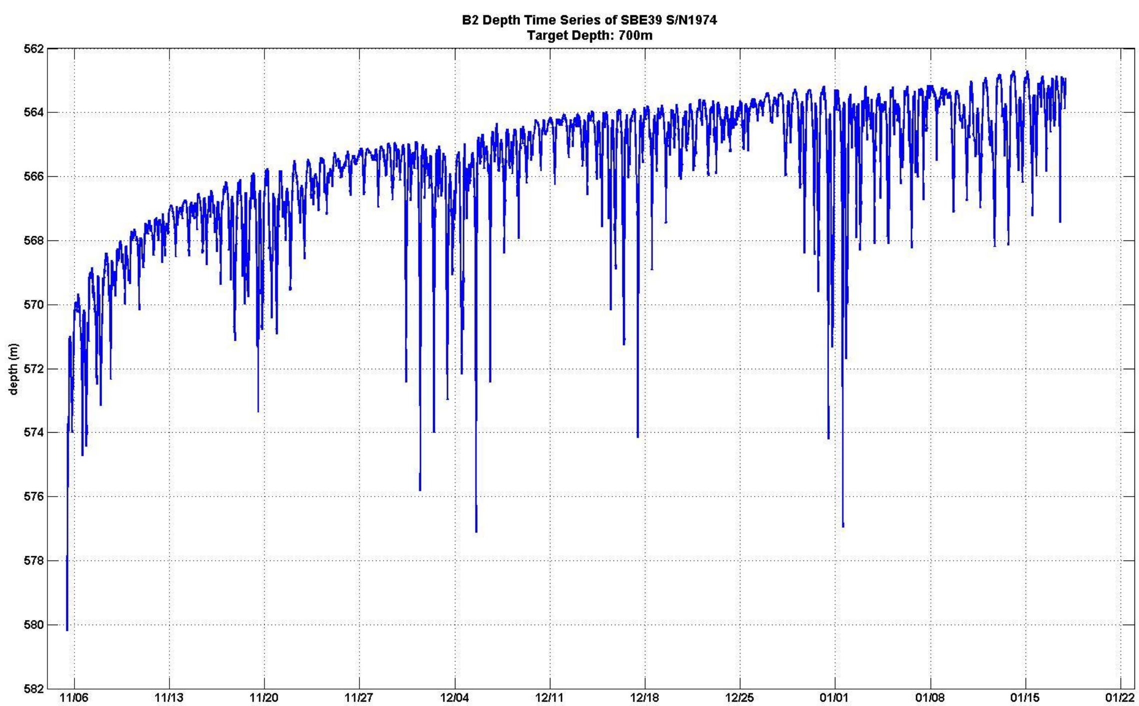


Figure 34. Pressure data from the Temperature/Pressure sensor deployed at a target depth of 700m. Nylon rope stretch is evident over the course of the deployment. Cyclic depth deviations are caused by the mooring tilt due to tidal currents.

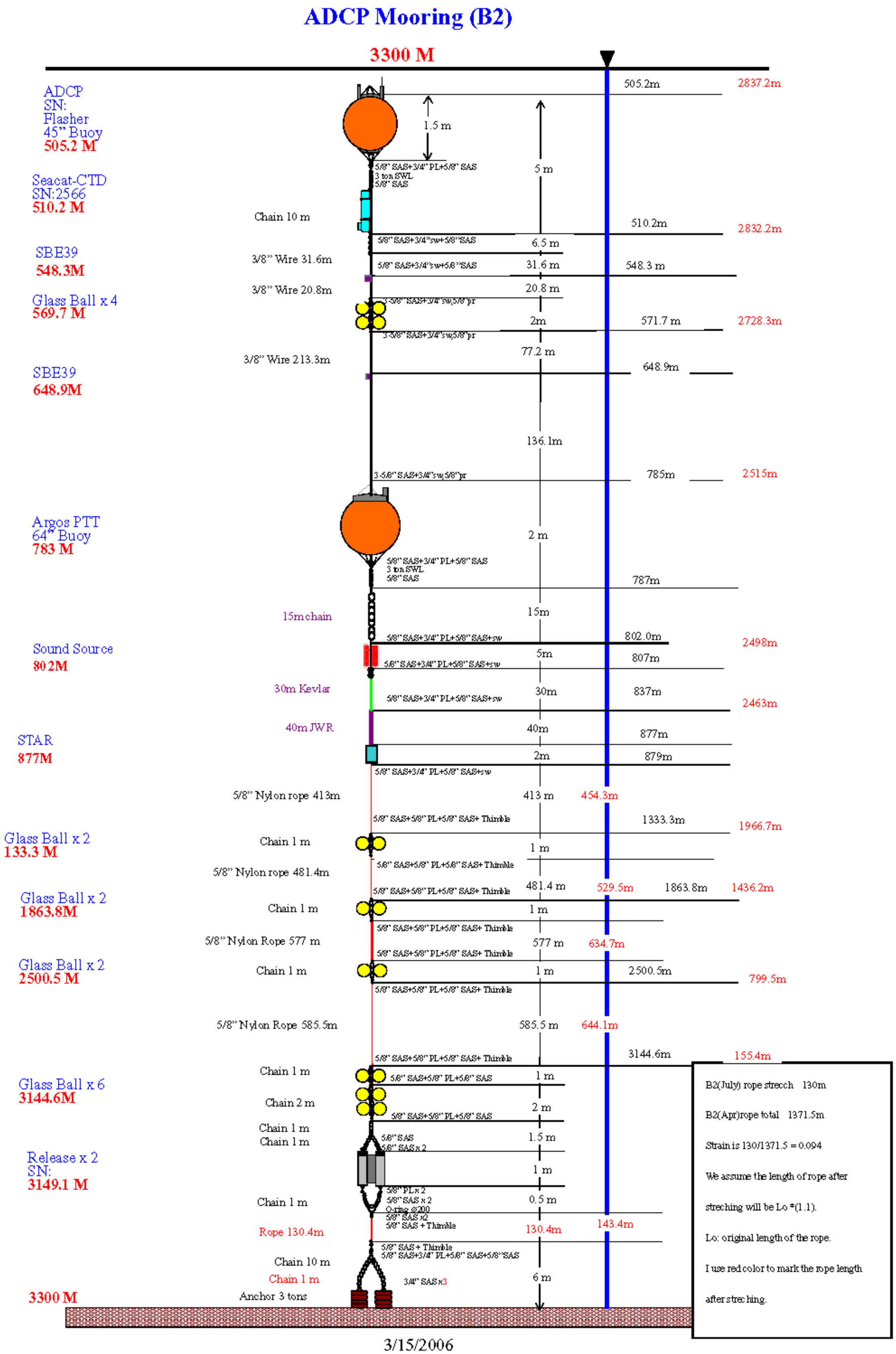


Figure 35. B2 mooring drawing, as deployed November 4, 2005. (NTU) The rope lengths noted on the right of the figure (in red) have been adjusted for the assumed rope stretch of 10%. Targeted instrument depths (left side) are not the actual deployed depths.

6.5 Simple Tomographic Acoustic Receiver (STAR)

Two Simple Tomographic Acoustic Receiver (STAR) systems (Figure 15), developed by Scripps Institution of Oceanography, were provided as backup receiver systems for the WISE basin experiment after the tomography receiver systems failed to record for the full deployment period. The STAR system is an autonomous receiver, capable of recording both acoustic time-series data from a 4-element hydrophone array, as well as the higher frequency navigation pings from the Benthos transponders. The STAR electronics also have a navigation transducer built-in, so we will take advantage of this capability to acoustically navigate for mooring motion.

Due to the loss of the B2 tomography source (SYS13), it was decided to deploy one STAR receiver on the B1 mooring as the primary acoustics receiver, and the remaining sound source (SYS11) on the B2 mooring. Power spectra of the B1 STAR receiver data is shown in Appendix B for all deployments.

Figure 36. Simple Tomographic Acoustic Receiver electronics package (photo courtesy of Lloyd Green, Scripps Institution of Oceanography).

The STAR electronics package was moored below the array elements, which is mounted onto torque balanced jacketed wire rope (JWR) as the strength member for mooring. The hydrophone elements are color coded for the STAR instrument, with the first hydrophone element (Red) ~5m above the STAR electronics, second phone element (Yellow) ~14m above,

third phone (Green) ~23m above, and the fourth phone (Blue) ~32m above the electronics end-cap. The total aperture of the hydrophone array is 27m, with the top hydrophone approximately 8m from the upper end of the JWR/swivel.

Figure 37. The rubber isolator used to mount the STAR array cable (bottom) to the jacketed wire-rope (top) for the 4-element, 32m aperture STAR array.

The STAR receiver hydrophones are manufactured by High Tech, Inc., model HTI-96-MIN/V voltage mode hydrophones. The raw hydrophone sensitivities are -201 dB re: 1V/µPa, with a built-in preamplifier gain of 41 dB for an overall sensitivity of -160 dB re: 1V/µPa at the end of the array cable. The preamplifier has a built-in high pass filter cutoff frequency at 10 Hz, and a low pass cutoff frequency of 5kHz. Originally assembled to listen to a source frequency of 250 Hz, the 4-element STAR array has a phone spacing of 9m.

Table 39. B1 mooring Acquisition Task for November – January deployment. (S/N 10)

Acquisition stop time	YD 385 00:00 UTC (January 20, 08:00 local)
Receive Task #1	00:01:50 every 1 hour from YD 1
Duration	60 seconds @ 1600 Hz, gain = 0 dB
Receive Task #2	00:16:50 every 1 hour from YD 1
Duration	60 seconds @ 1600 Hz, gain = 0 dB
Receive Task #3	00:31:50 every 1 hour from YD 1
Duration	60 seconds @ 1600 Hz, gain = 0 dB
Receive Task #4	00:41:50 every 1 hour from YD 1
Duration	60 seconds @ 1600 Hz, gain = 0 dB

NAV Ping	10.5 kHz at 00:10:00 every 1 hour
NAV receiver duration	15 seconds (no process, save raw)
Daily task	00:18:50 every day
Rb task	00:26:50 every day

Table 40. November 2005 – January 2006 STAR S/N 10 timing checks (B1).

System time (UTC) DDD HH:MM:SS	Deck Box time (UTC) DDD HH:MM:SS.SSSSSS
306 10:07: 57.999653	306 10:07:58
306 10:09: 03.999653	306 10:09:04
Average Δt at deployment	-0.000347s (STAR timing slow)
417 00:54:26.834070	052 00:54:26
417 00:55:42.834070	052 00:55:42
Average Δt at recovery	+0.834070 (STAR timing fast)
Drift rate	**+7543.3855 usec/day (advancing)**

Table 41. B2 mooring Acquisition Task for November – January deployment. (S/N 11)

Acquisition stop time	YD 385 00:00 UTC (January 20, 08:00 local)
Receive Task #1	00:05:00 every 1 hour from YD 1
Duration	60 seconds @ 1600 Hz, gain = 0 dB
Receive Task #2	00:20:00 every 1 hour from YD 1
Duration	60 seconds @ 1600 Hz, gain = 0 dB
Receive Task #3	00:35:00 every 1 hour from YD 1
Duration	60 seconds @ 1600 Hz, gain = 0 dB
Receive Task #4	00:50:00 every 1 hour from YD 1
Duration	60 seconds @ 1600 Hz, gain = 0 dB
NAV Ping	10.0 kHz at 00:10:00 every 1 hour
NAV receiver duration	15 seconds (no process, save raw)
Daily task	00:22:00 every day
Rb task	00:30:00 every day

Table 42. November 2005 - January 2006 STAR S/N 11 timing checks (B2).

System time (UTC) DDD HH:MM:SS	Deck Box time (UTC) DDD HH:MM:SS.SSSSSS
309 05:46:09.999710	309 05:46:10
Average Δt at deployment	(STAR timing slow)
------------	------------
Average Δt at recovery	------------
Drift rate	------------

7.0 Basin Experiment (February 2006)

The winter cruise to recover, re-battery, and redeploy the WISE moorings was conducted February 19-27, 2006 on board the R/V OCEAN RESEARCHER 1.

7.1 NPS STAR receiver, Physical Oceanography (B1) mooring

B1 mooring recovery began at 22:16 UTC on February 20th, 2006, with the hard hats on the surface 30 minutes after release. Winds to 20 kts, NNE with 4-7 foot swells during the recovery effort. B1 recovery was completed by 21 February, 02:46 UTC, and data download of all instruments commenced. B1 redeployment occurred between 11:39 – 17:15 UTC on 21 February 2006.

Table 43. February - June 2006 'B1' deployment information.

Deployed (date/time UTC)	21 February 2006 (YD 52), 17:15 GMT
Latitude N (anchor drop)	21° 21.994'
Longitude E (anchor drop)	118° 35.880'
Water depth (anchor drop)	2478 m
Latitude N (surveyed)	21° 21.8586' N
Longitude E (surveyed)	118° 35.7808' E
Receiver depths (CH0 = deepest)	857m, 848m, 839m, 830m

Table 44. B1 mooring Acquisition Task for February - May deployment (STAR S/N 10)

Receive Task #1	00:01:45 every 1 hour from YD 1
Duration	65 seconds @ 1600 Hz, gain = 0 dB
Receive Task #2	00:16:45 every 1 hour from YD 1
Duration	65 seconds @ 1600 Hz, gain = 0 dB
Receive Task #3	00:31:45 every 1 hour from YD 1
Duration	65 seconds @ 1600 Hz, gain = 0 dB
Receive Task #4	00:46:45 every 1 hour from YD 1
Duration	65 seconds @ 1600 Hz, gain = 0 dB
NAV Ping	10.5 kHz at 00:10:00
NAV task	00:09:55 every 1 hour
NAV receiver duration	15 seconds per reply (raw data)
Daily task	00:18:50 every day
Rb task	00:26:50 every day

Table 45. February - May 2006 STAR S/N 10 timing checks (B2).

System time (UTC) DDD HH:MM:SS.SSSSSS	Deck Box time (UTC) DDD HH:MM:SS
052 13:06:54.000129	052 13:06:54
052 13:08:05.000130	052 13:08:05
052 13:10:10.000130	052 13:10:10
Average Δt at deployment	+0.000130s (STAR timing fast)
153 11:46:11.848538	153 11:46:12
153 11:46:45.848538	153 11:46:46
Average Δt at recovery	-0.151462 s (STAR timing is slow)
Drift rate	**-1.508 msec/day**

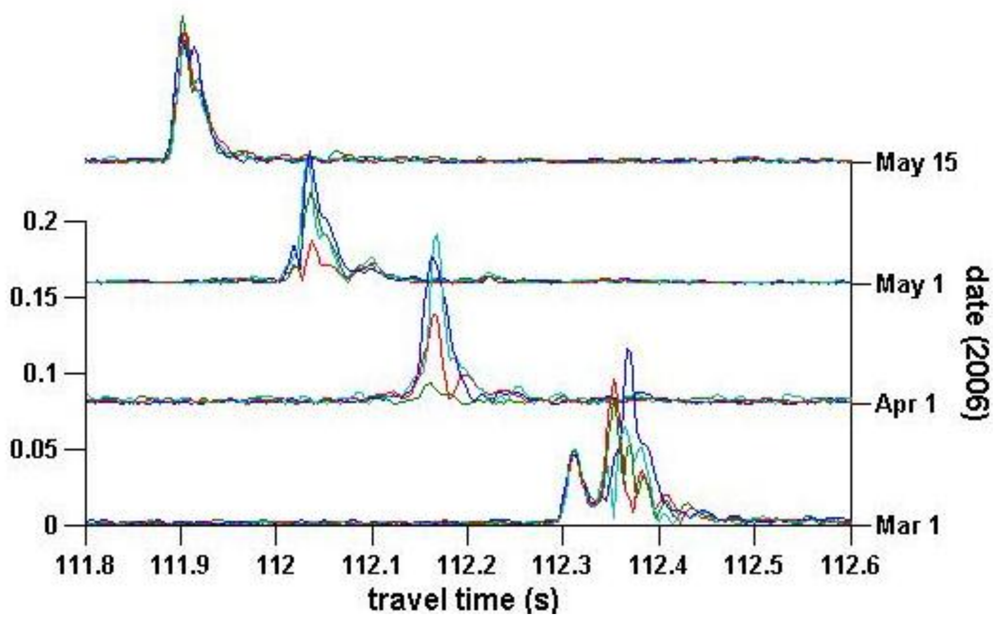


Figure 38. B1 coherent arrival structures over the deployment. Each date shows the single-phone coherent arrival structures from the 00:01:45 reception. The multi-path variability is evident over the deployment period (clock drifts have not been applied to correct the visible temporal shift in this figure).

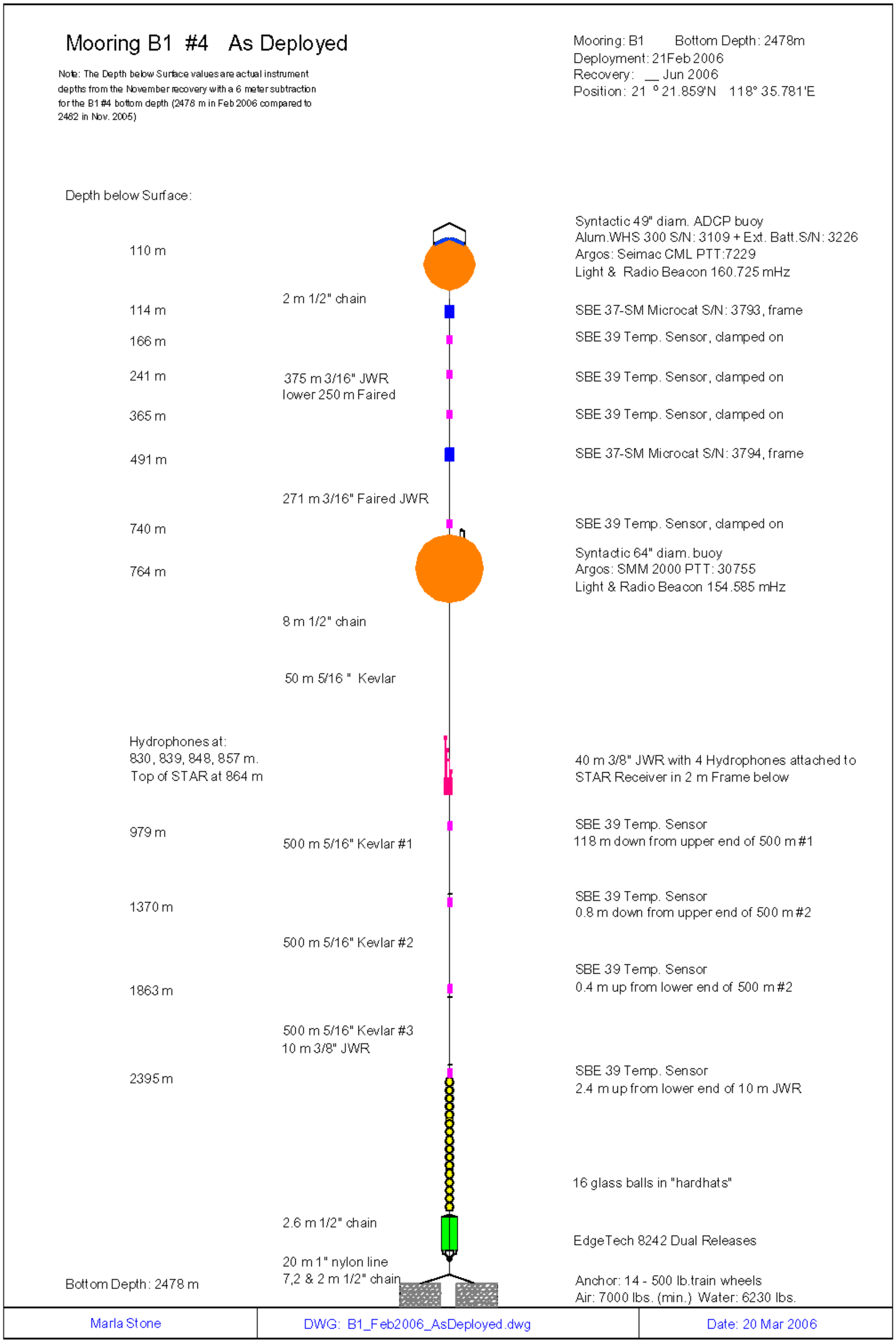


Figure 39. B1 mooring design, as deployed February 21, 2006.

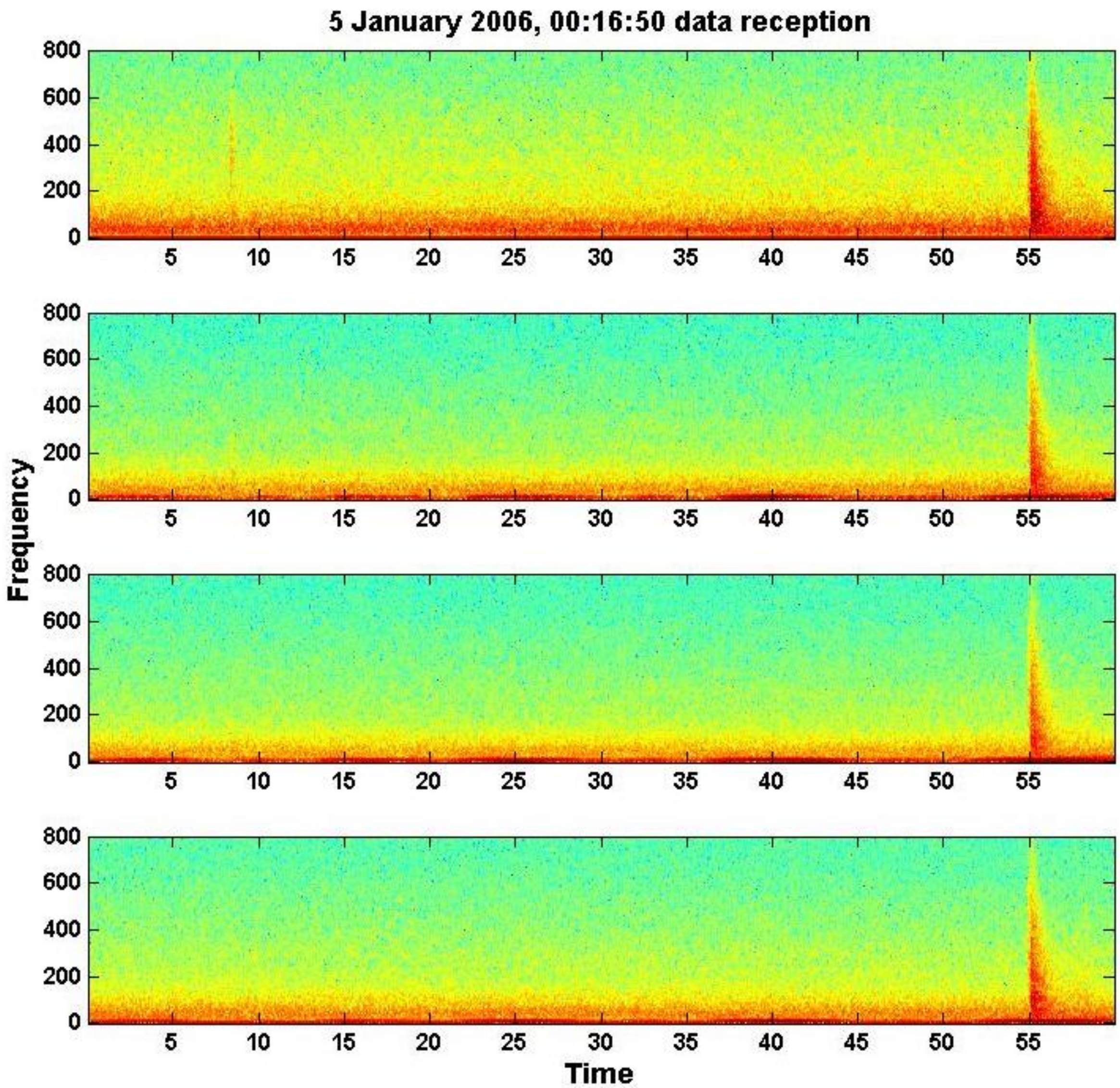


Figure 40. Receiver data spectrograms from the B1 STAR hydrophones showing the broadband point sources (~55 seconds into the files) typical of the local Chinese fishing activity.

7.2 NPS 400 Hz SYS11 sound source (B2 mooring)

The B2 mooring was released at 07:00 UTC on 22 February. The actual mooring recovery effort was delayed, when the hardhat floatation above the acoustic releases were damaged by the ship's props, severing the mooring lines and sending the releases and floatation to the bottom. Mooring efforts resumed from the next set of hardhats at 09:34, and the recovery effort was completed at 13:07 GMT.

A quick look at the B1 STAR reception files showed that the SYS11 transmission arrival structures were not clearly present in the receiver data. It was noted that there continues to be some uncertainty about the B2 instrument depths, and a pressure sensor from the October deployment suggested that the depths may be off as much as -120m (shallow biased). The source target depth of the B2 mooring was changed to 1000m depth, to ensure that the transmitter will be in the deep sound channel.

It was decided to take advantage of a moderate weather window to turn the source around at sea, rather than returning to port, as the severe weather had caused us to use much of our remaining ship time for the cruise. Several hours into the turn-around the weather started turning bad. Unfortunately, a CTD cast was underway when large swells were encountered, and the ship was forced to maneuver due to the CTD rosette over the side. This maneuver put the ship on a bad heading, causing a large swell to break over the stern of the ship, and a 3' surge of water washed the sound source, the source battery, and all equipment that was on deck. The original battery voltage of 48.6 Vdc dropped to 48.0 Vdc after the water bath. The source battery pack is composed of 30 individual pucks, each diode protected, parallel wired to achieve the supply power for the sound source. It is uncertain if there was damage to any of the individual pucks, and the closest spare battery was ashore, it was decided to install the battery and proceed with the deployment.

The redeployment of the B2 mooring was postponed due to steady 35 kts winds, gusting to 50 kts, and 12-15 foot seas after recovery operations. Redeployment took place 26 February between 02:00Z and 06:26Z.

At the time of the source deployment, the next cruise dates had not been confirmed, but would not be sooner than May 16th, so the sound source was programmed to turn off May 16, 2006 at 08:00 local time.

Table 46. February - May 2006 'B2' deployment information (SYS11)

Deployed (date/time UTC)	2/26/06 (YD 57) 06:26 GMT
Latitude N (anchor drop)	20° 56.137' N
Longitude E (anchor drop)	120° 08.203' E
Water depth (m)	3352 m
Latitude N (surveyed)	20° 56.0979' N

Longitude E (surveyed)	120° 7.9780' E
Fall back (anchor drop to surveyed position)	395.7 m
Source depth (m)	999.5 m

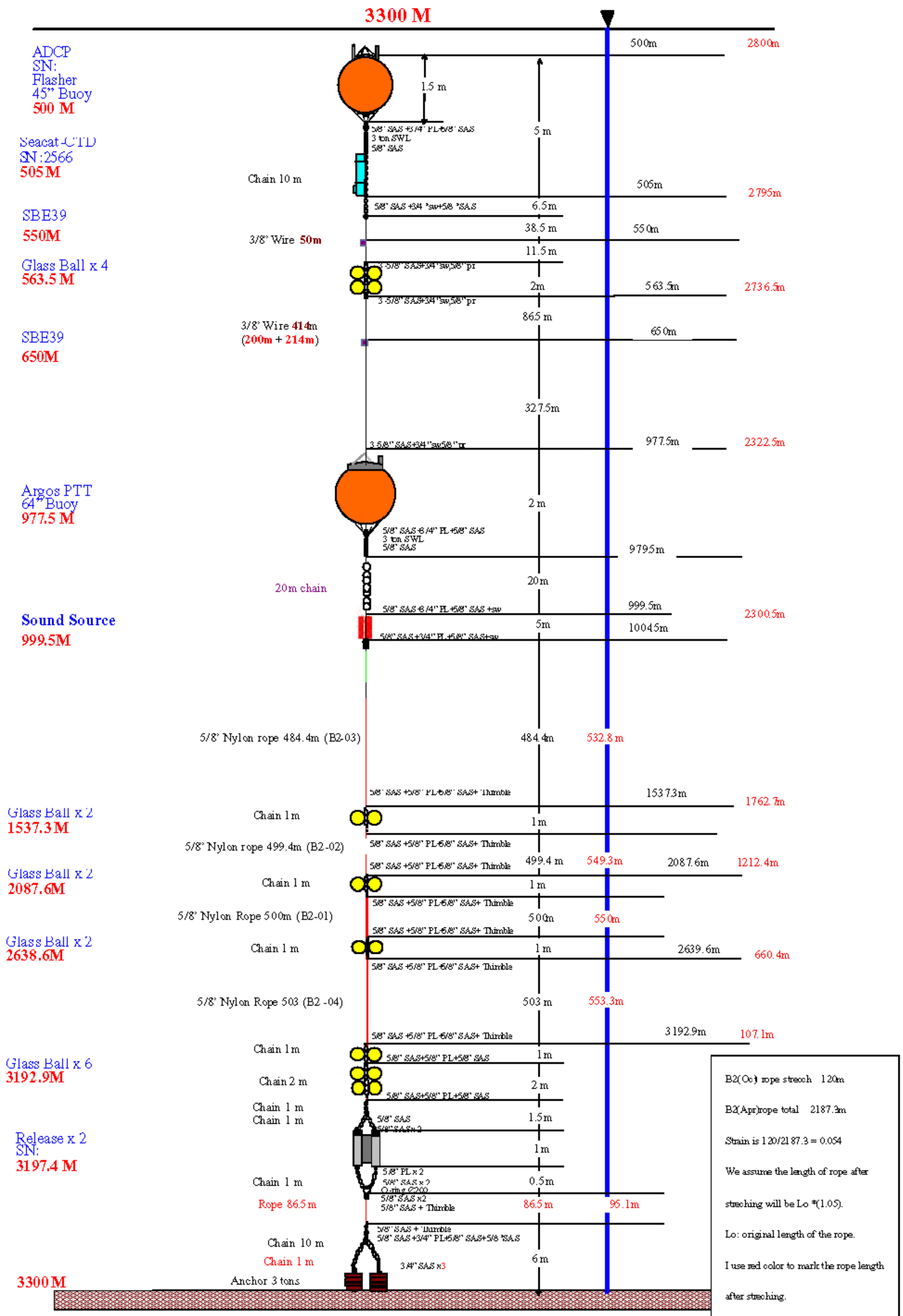
Table 47. February – May 2006 'B2' source timing checks (clock #CK64)

System time (UTC) DDDD HH MM SS	GPS SAIL time (UTC) DDDD HH MM SS.SSSSSS
3791 12:28:51	3791 12:28:51.000523
Average Δt at deployment	-0.000523s (source timing slow)
3890 08:29:32	3890 08:29:31.924324
3890 08:31:16	3890 08:31:15.924325
3890 08:31:28	3890 08:31:27.924325
Average Δt at recovery	+0.07567533s (source timing fast)
Drift rate	**+770.964 μsec/day**

Table 48. February - May 'B2' source transmission schedule (SYS11).

Start time (UTC)	27 February 2006, 00:00 GMT (08:00 local, YD 58)
Stop time (UTC)	16 May 2006, 00:00:00 GMT (08:00 local, YD 136)
Transmission times (minutes after the hour)	0, 15, 30, 45
Center frequency (Hz)	400
Bandwidth (Hz)	100
Source level	180 dB re 1 μPa @ 1m
Cycles per digit	4
Digit width	10 ms
Digits per sequence (sequence duration)	511 (5.11 s)
Number of sequences transmitted (transmission duration)	10 (51.10 s)
m-sequence LAW (octal)	1021
Sequence initialization	000000001
Phase modulation angle	87.46035°

ADCP Mooring (B2)



3/16/2006

Figure 41. B2 mooring drawing, as deployed February 26, 2006. (NTU)

7.3 ADCP mooring (S7 mooring)

The S7 mooring was recovered 24 February at 10:20 GMT. All sensors were recovered in good condition, however there was lots of fishing line and tackle on the entire mooring, from the surface float down to the acoustic release hardhats. The current meter vanes may be fouled and not able to move with the current (especially the deep RCM-8, S/N 9260).

Figure 42. Fishing line and tackle fouling the S7 mooring.

Table 49. S7 ADCP mooring information - February 2006.

Deployed (date/time UTC)	24 February 2006 (YD 55)
Latitude N (anchor drop)	21° 36.2055’
Longitude E (anchor drop)	117° 16.8589’
Water depth (anchor drop)	346 m

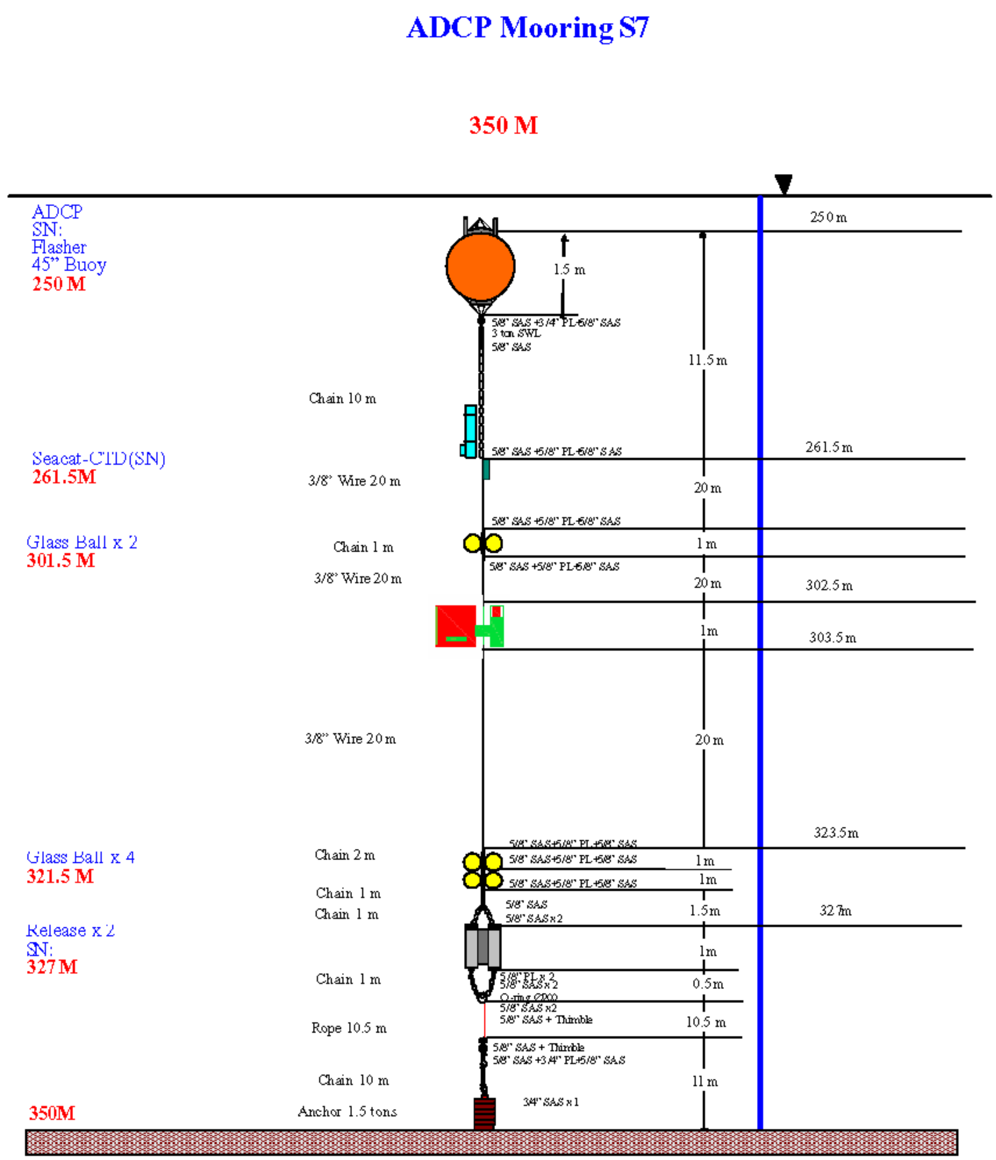


Figure 43. ADCP mooring S7 (as deployed), February 29, 2006. (NTU)

8.0 Basin Experiment (June 2006)

The WISE/VANS Spring cruise to recover, re-battery and redeploy the basin moorings was conducted 1-9 June 2006 on board the R/V OCEAN RESEARCHER 1, with its newly installed deck crane.

8.1 STAR Receiver (B1 mooring)

B1 mooring recovery began at 09:08 UTC on June 2nd, 2006, with the recovery of the ADCP buoy commencing at 09:28 UTC. B1 recovery was completed by 12:06 UTC, and data download of all instruments commenced. B1 redeployment occurred between 17:15 – 19:38 UTC on 6 June 2006. The upper part of the B1 mooring (Physical Oceanography instruments) was recovered on this cruise as this was the conclusion of the Physical Oceanography component of the WISE experiment. The lower, acoustic section of this mooring was redeployed in an extended effort to collect acoustic data.

Table 50. June - October 2006 'B1' deployment information.

Deployed (date/time UTC)	06 June 2006 (YD 157), 19:38 GMT
Latitude N (anchor drop)	21° 21.83'
Longitude E (anchor drop)	118° 35.81'
Water depth (anchor drop)	2485 m
Latitude N (surveyed)	21° 21.8688' N
Longitude E (surveyed)	118° 35.814' E
Fall back (anchor drop to surveyed position)	71.9 m
Receiver #HTI-01-250Hz	S/N: 27450101, Date Code 08-01
Receiver depths (CH0 = deepest)	875m, 866m, 857m, 848m

Due to the extended deployment of this mooring, two older, but unused batteries manufactured by Battery Specialties were installed in STAR S/N 11. Receiver tasks were modified from the previous deployment, based on the data recovered from S/N 10 from the October data set. All transponder replies during the Navigation task are received within 9 seconds, so the NAV task is being reduced to a 10 second window per reply. Similarly, the Receive task window is being reduced to 40 seconds, to ensure sufficient battery power remains to cover the full 5 month deployment.

Table 51. B1 mooring Acquisition Task for June - October 2006 deployment (STAR S/N 11)

Receive Task #1	00:01:50 every 1 hour from YD 1
Duration	40 seconds @ 1600 Hz, gain = 0 dB
Receive Task #2	00:16:50 every 1 hour from YD 1
Duration	40 seconds @ 1600 Hz, gain = 0 dB
Receive Task #3	00:31:50 every 1 hour from YD 1
Duration	40 seconds @ 1600 Hz, gain = 0 dB
Receive Task #4	00:46:50 every 1 hour from YD 1
Duration	40 seconds @ 1600 Hz, gain = 0 dB
NAV Ping	10.5 kHz at 00:10:00
NAV task	00:09:55 every 1 hour
NAV receiver duration	10 seconds per reply (raw data)
Daily task	00:18:25 every day
Rb task	00:26:25 every day

Table 52. June - October 2006 STAR S/N 11 timing checks (B1).

System time (UTC) DDD HH:MM:SS.SSSSSS	**Deck Box time (UTC) DDD HH:MM:SS**
155 07:52:52.006196	155 07:52:52
Average Δt at deployment	+0.006196 s (receiver time is fast)
302 00:41:09.147671	302 00:41:09
302 00:42:32.147671	302 00:42:32
Average Δt at recovery	+0.147671 s (receiver time is fast)
Drift rate	**+964.375 usec/day**

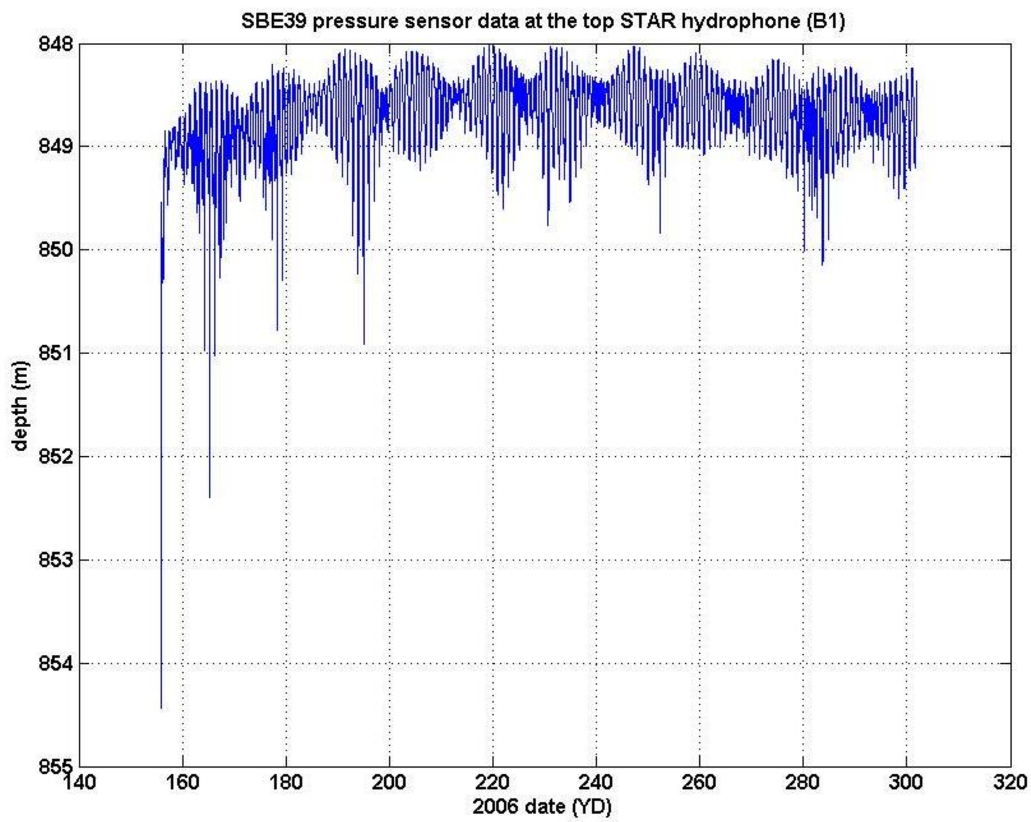


Figure 44. B1 pressure sensor data located near the top STAR hydrophone.

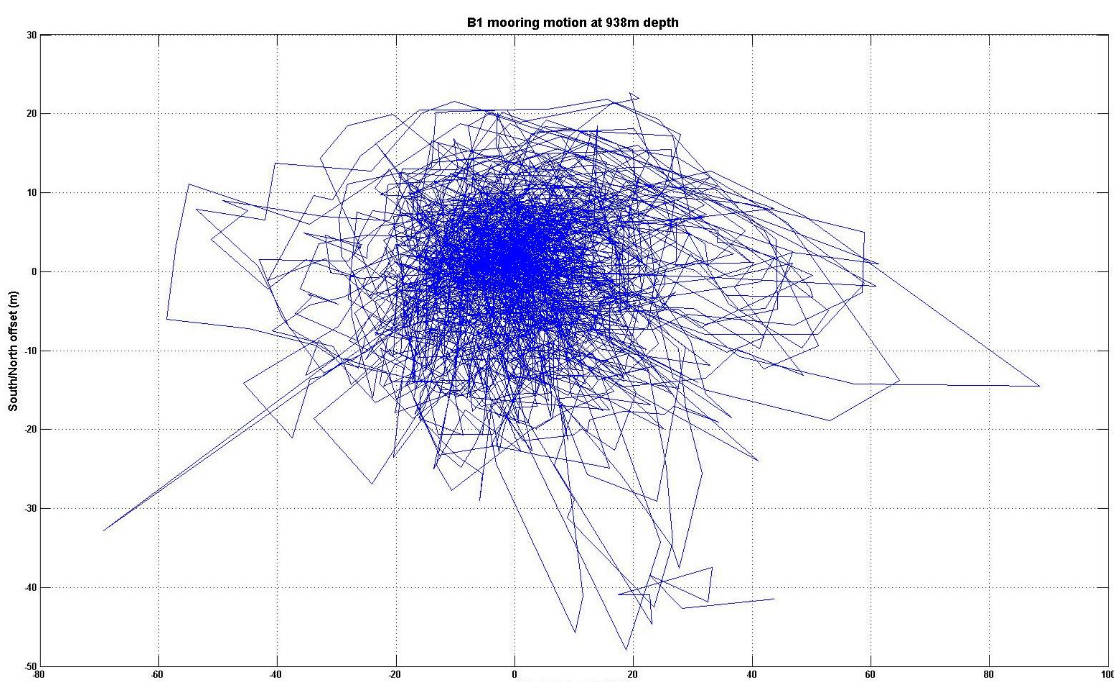


Figure 45. B1 mooring motion at 884m depth (STAR NAV transducer).

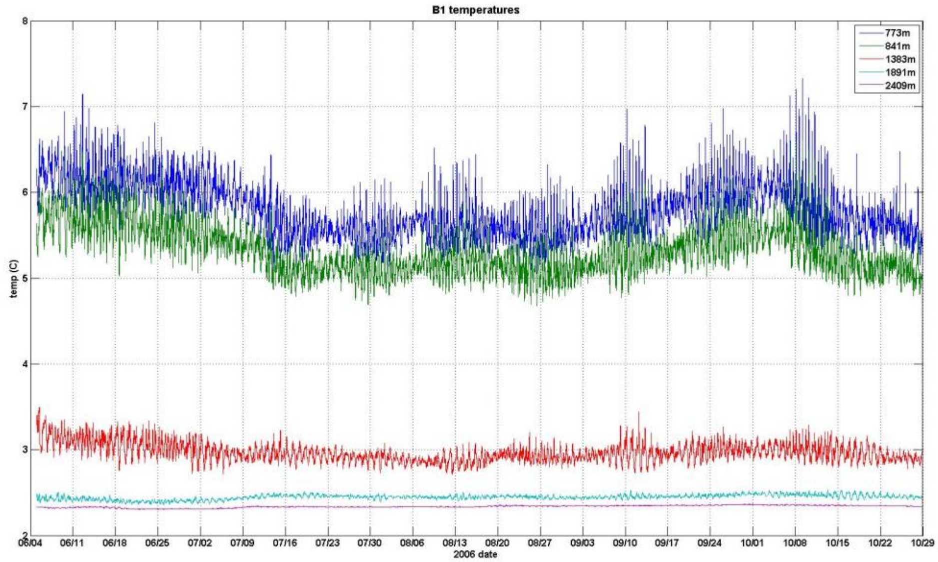


Figure 46. B1 temperatures over the June-October 2006 deployment. (Shown at 773, 841, 1383, 1891 and 2409m depth.)

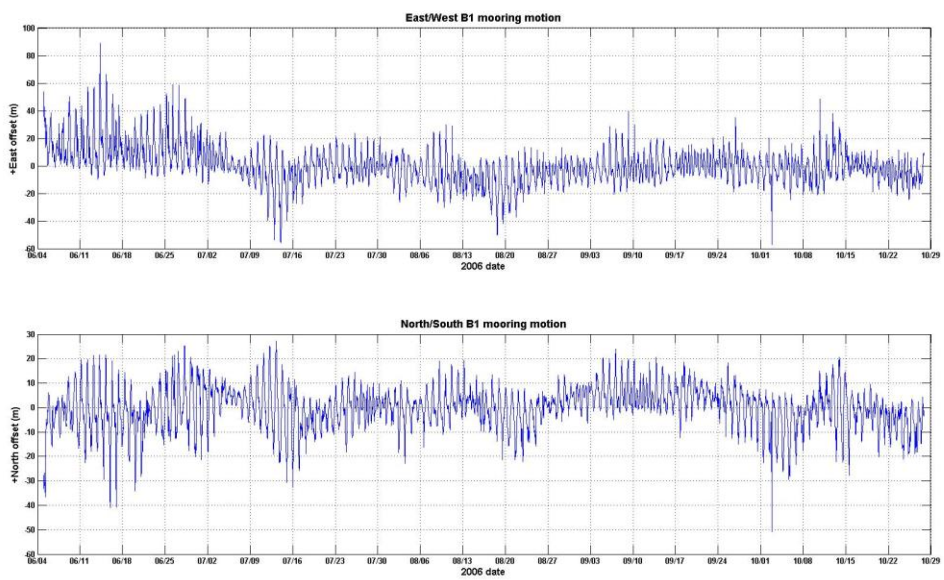


Figure 47. B1 mooring motion offsets in the East/West (top) and North/South (bottom) directions during the June - October 2006 deployment at 884m depth.

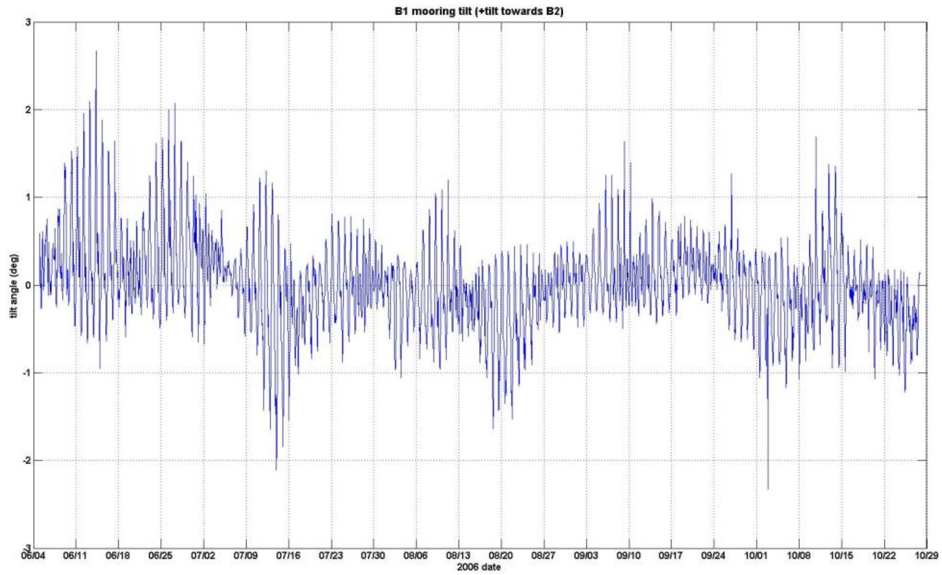


Figure 48. B1 mooring motion tilt angle (degrees), along the propagation path. Positive tilt angle is in towards the B2 mooring.

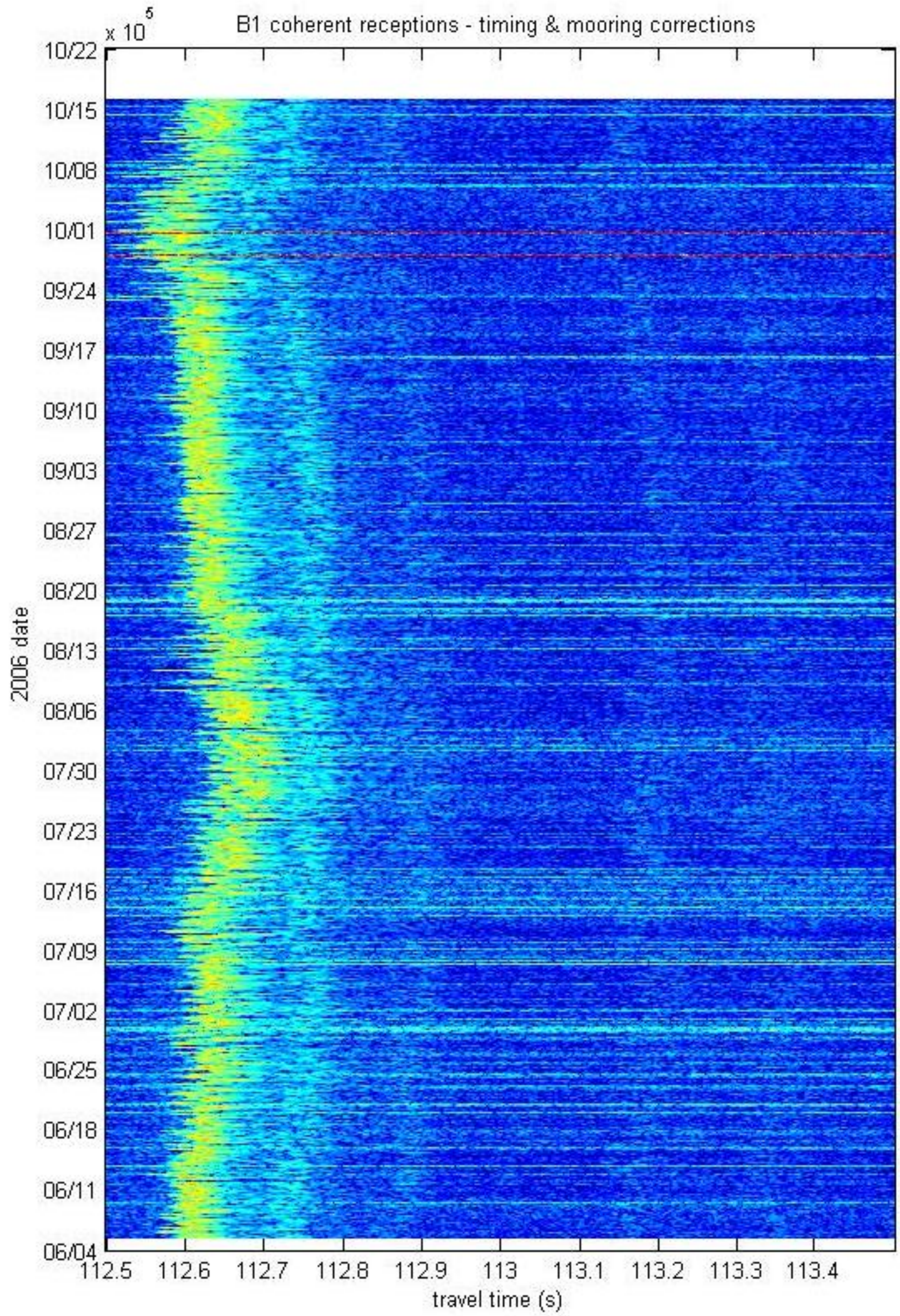


Figure 49. Acoustic arrival structures over the June-October 2006 deployment.

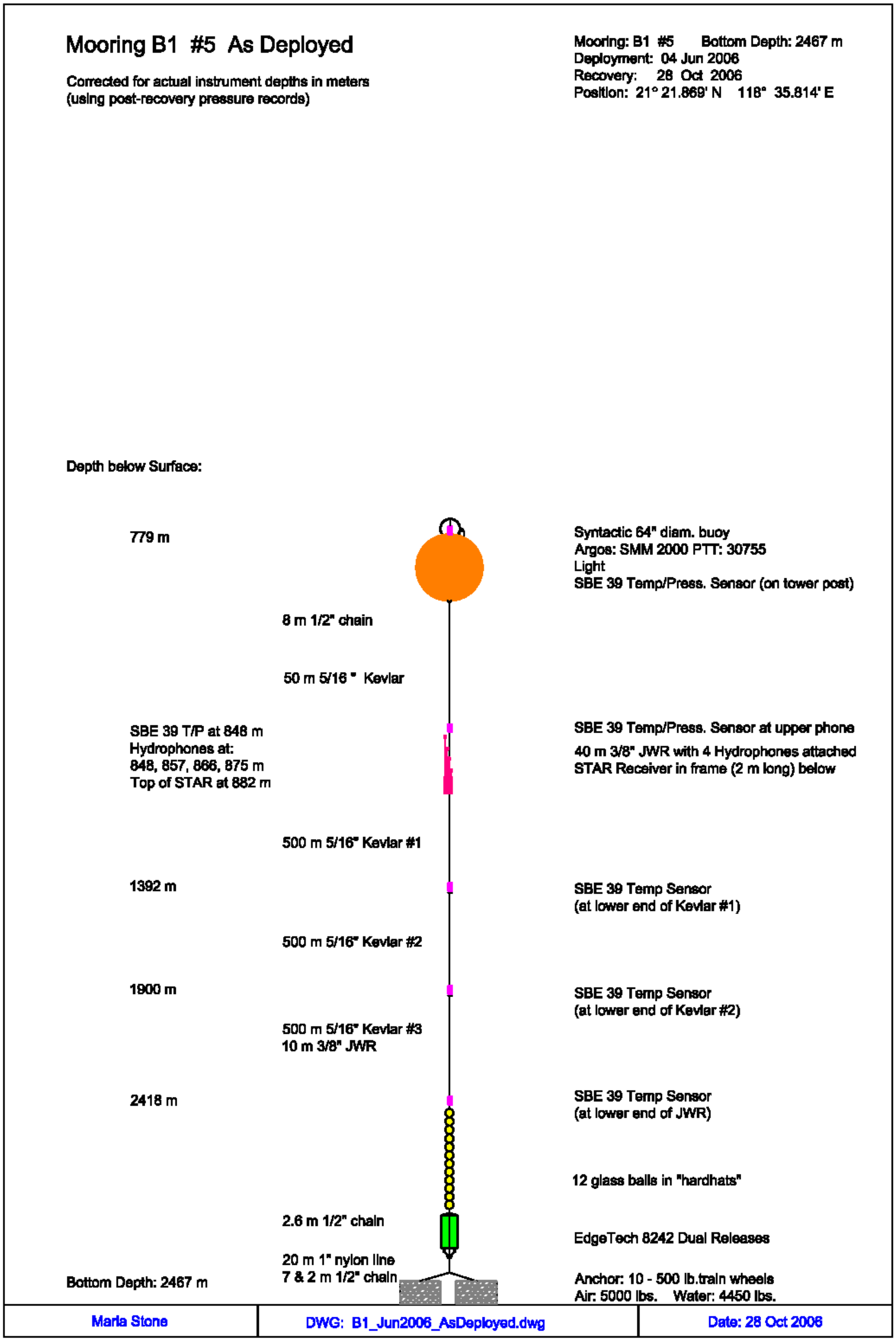


Figure 50. B1 mooring drawing, as deployed June 4, 2006.

8.2 NPS 400 Hz SYS11 sound source (B2 mooring)

The OR1 arrived at the B2 mooring at 0500L on 1 June 2006 (21:00 GMT, 5/31/06) for mooring recovery operations. The mooring was on deck by 08:30 L (00:30 GMT), and the ship continued to B1 for recovery operations.

June 5, 2006 13:30L (05:30 GMT) we returned to station B2, conducted a CTD cast, and deployed the mooring. Mooring operations began at 09:24 GMT, with the source in water at 09:28 and the STAR receiver deployed at 09:40 GMT. Mooring operations were completed at 19:28 L (11:28 GMT).

Table 53. June - October 2006 'B2' deployment information (SYS11)

Deployed (date/time UTC)	6/5/06 11:28 GMT (YD 156)
Latitude N (anchor drop)	20° 56.1950' N
Longitude E (anchor drop)	120° 08.1135' E
Water depth (m)	3350 m
Latitude N (surveyed)	20° 56.1731' N
Longitude E (surveyed)	120° 8.3388' E
Fall back (anchor drop to surveyed position)	392.7 m
Source depth (m)	840 m

Table 54. June – October 2006 'B2' source timing checks (clock #CK64)

System time (UTC) DDDD HH MM SS	GPS SAIL time (UTC) DDDD HH MM SS.SSSSSS
3891 08:44:39	3891 08:44:38.999744
3891 08:44:46	3891 08:44:45.999745
3891 08:44:57	3891 08:44:56.999745
Average Δt at deployment	+0.000255s (source timing fast)
4035 02:16:10	4035 02:16:09.863360
4035 02:16:19	4035 02:16:18.863361
4035 02:16:30	4035 02:16:29.863362
Average Δt at recovery	+0.136639s (source timing fast)
Drift rate	**+948.889 usec/day**

Table 55. June – October 2006 'B2' source transmission schedule (SYS11).

Start time (UTC)	5 June 2006, 3891:14:00:00 GMT (08:00 local, YD 156)
Stop time (UTC)	15 October 2006, 4023:00:00:00 GMT (08:00 local, YD 288)
Transmission times (minutes after the hour)	0, 15, 30, 45
Center frequency (Hz)	400
Bandwidth (Hz)	100
Source level	180 dB re 1 μPa @ 1m
Cycles per digit	4
Digit width	10 ms
Digits per sequence (sequence duration)	511 (5.11 s)
Number of sequences transmitted (transmission duration)	7 (35.77 s)
m-sequence LAW (octal)	1021
Sequence initialization	000000001
Phase modulation angle	87.46035°

Table 56. B2 mooring Navigation Task for June - October 2006 deployment (STAR S/N 10)

Receive Task #1	00:01:50 every 12 hours every 2 days from YD 1
Duration	15 seconds @ 1600 Hz, gain = 0 dB
NAV Ping	10.0 kHz at 00:10:00
NAV task	00:09:55 every 1 hour
NAV receiver duration	10 seconds per reply (raw data)
NAV Transducer depth	938 m
Daily task	00:18:25 every day
Rb task	00:26:25 every day

Table 57. June - October 2006 STAR S/N 10 timing checks (B2).

System time (UTC) DDD HH:MM:SS.SSSSSS	Deck Box time (UTC) DDD HH:MM:SS
155 04:31:53.000178	155 04:31:53
155 04:35:34.000179	155 04:35:34
Average Δt at deployment	+0.0001785 s (receiver time is fast)
300 02:58:35.779542	300 02:58:36
300 03:03:41.779544	300 03:03:42
300 03:04:31.779544	300 03:04:32
Average Δt at recovery	-0.2204567s (receiver time is slow)
Drift rate	**-1.522 msec/day**

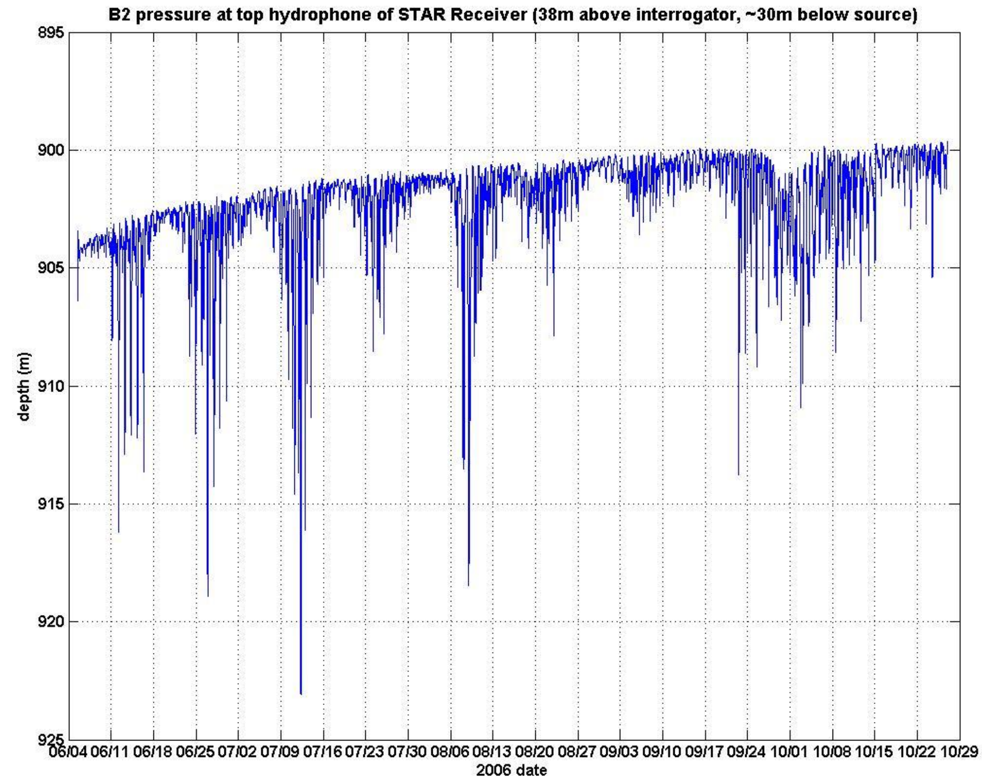


Figure 51. B2 Pressure sensor at top STAR hydrophone.

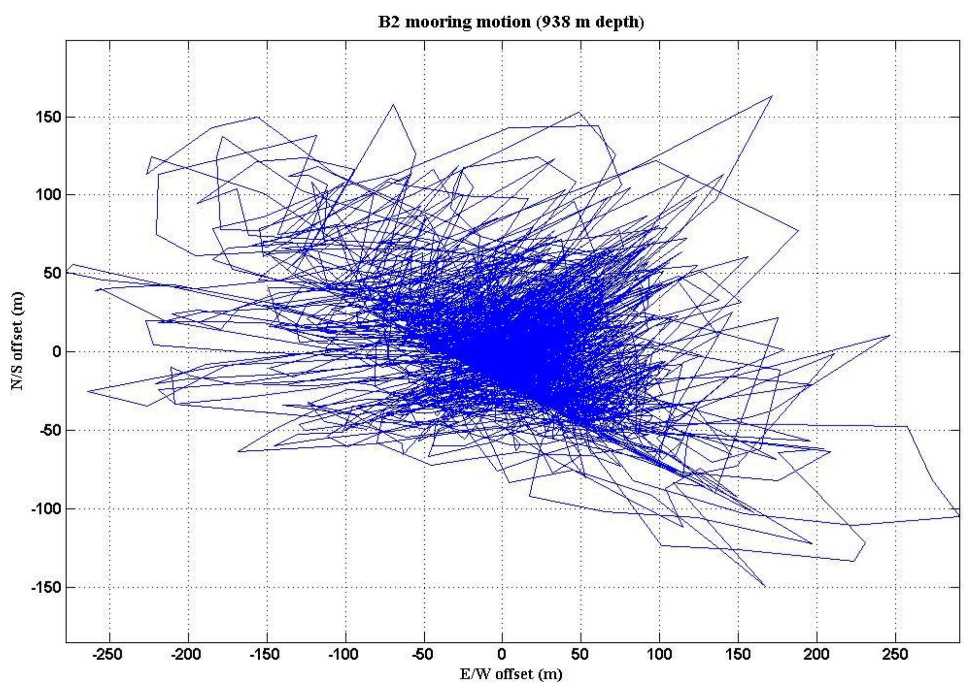


Figure 52. B2 mooring motion at 938m depth (STAR NAV transponder depth).

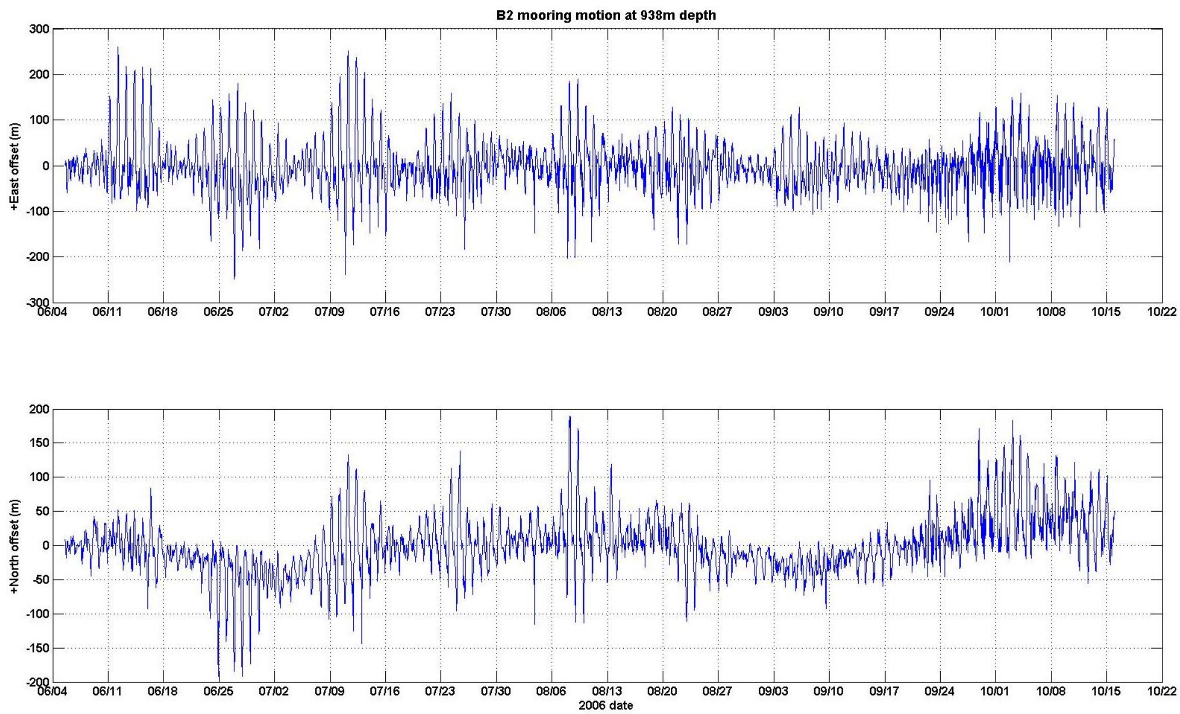


Figure 53. B2 mooring motion offset (m) in the East/West (top) and North/South (bottom) directions over the June - October 2006 deployment at 938m depth..

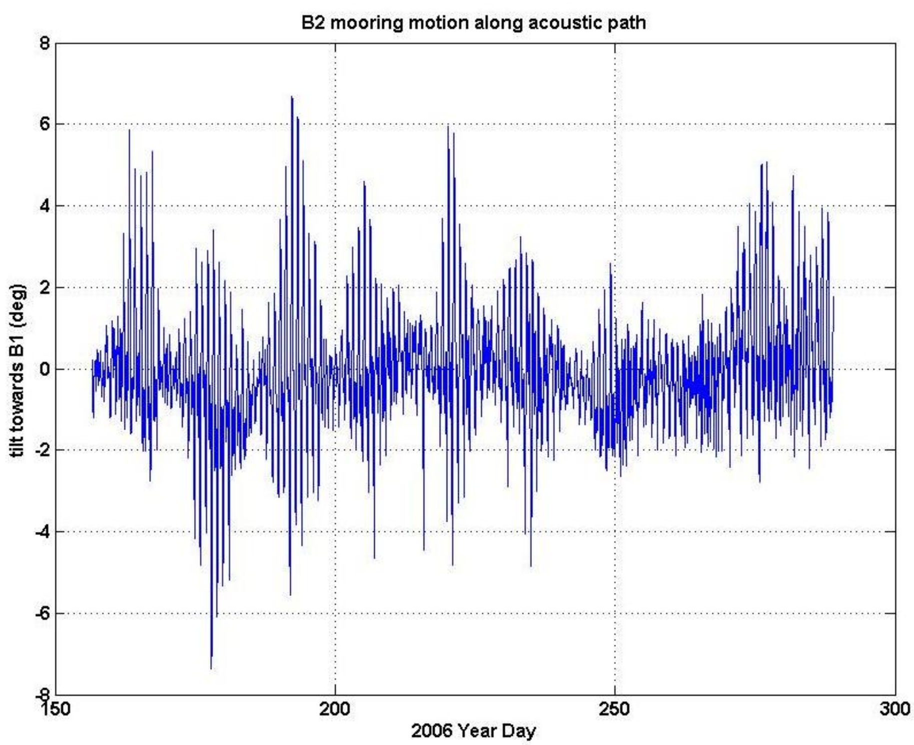


Figure 54. B2 mooring tilt along the acoustic path (positive tilt is towards the B1 mooring) calculated from the acoustic navigation.

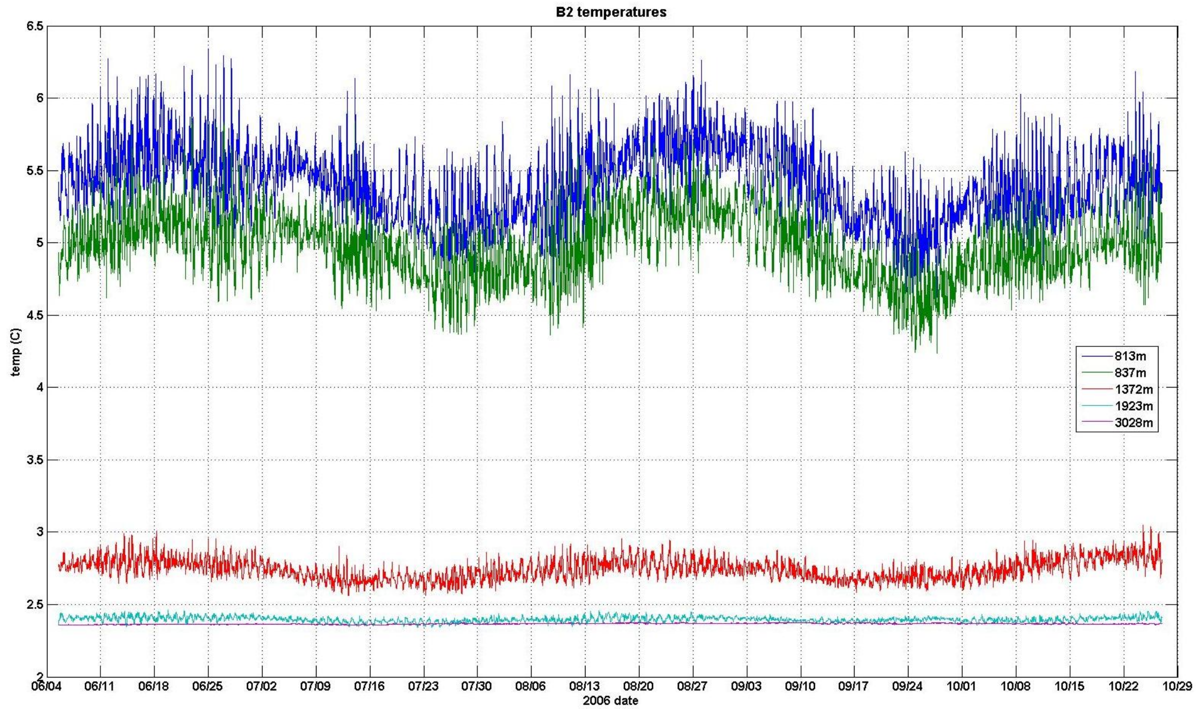


Figure 55. B2 temperatures over June - October 2006 deployment (shown at 813, 837, 1372, 1923 and 3028 meters depth).

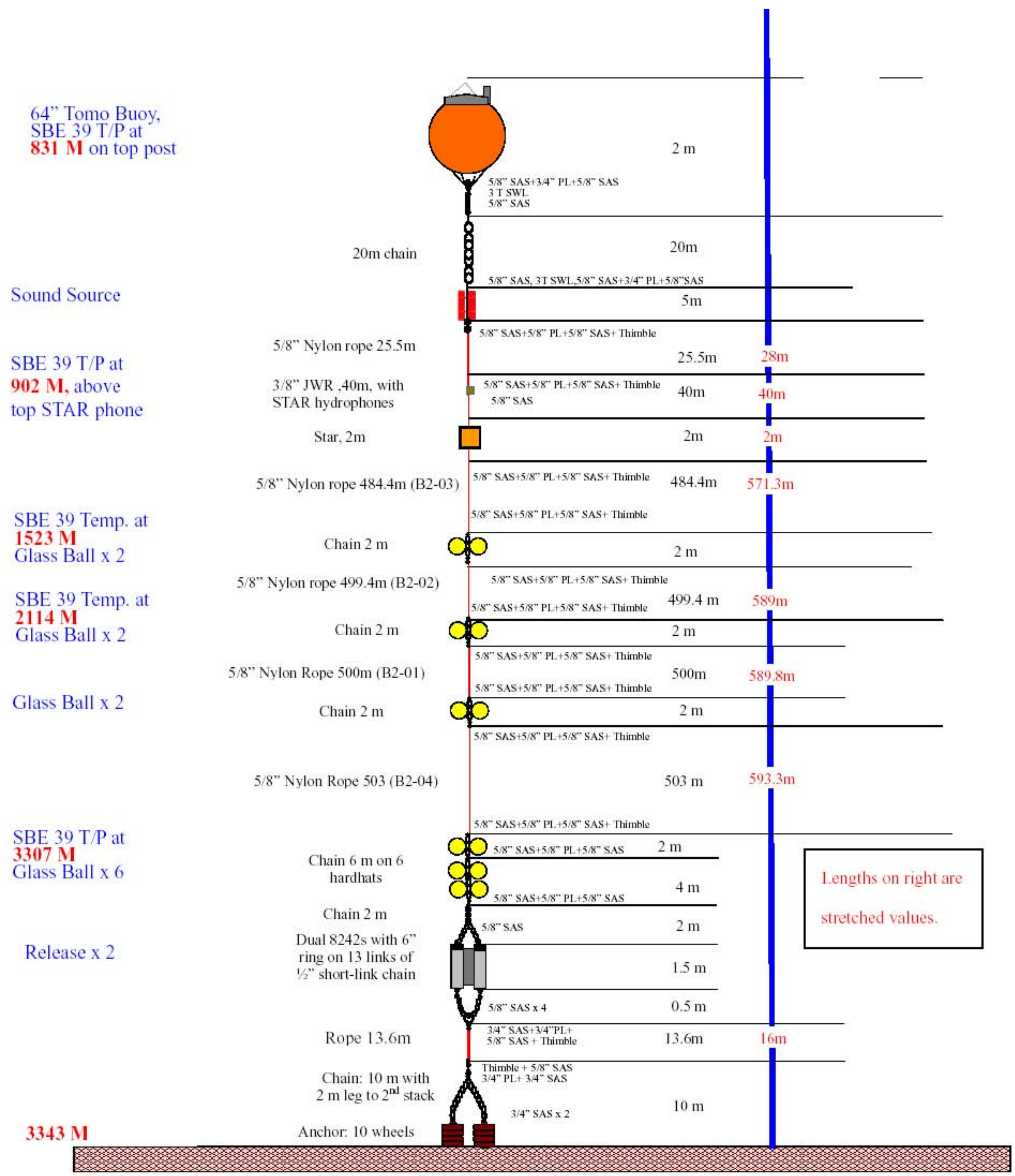


Figure 56. B2 mooring, as deployed June 5, 2006. Depths corrected for actual instrument depths (m), using post-recovery pressure records.

8.3 Sonobuoy transect

Sonobuoys were deployed along the B2-B1 transmission path to provide additional transmission loss information to that collected during the April 2005 cruise (section 4.4 of this report). All buoys were omni-directional AN-SSQ57B sonobuoys set to 3 hour lifespan, and 400' phone depth. Data collection was done using the MatLab Data Acquisition Toolbox function 'daqread.m', a National Instruments' DAQ card sampling at 80kHz, 60 second files, ±5V input range using ICOM radio #6 (model PCR-1000), with a radio volume set to 60% in the TalkPCR software (used to tune the radio frequency).

Table 58. Sonobuoy drop locations during the June 2006 cruise.

GPS Time (UTC)	Sonobuoy CH#	Distance from B1 (km)	Depth (m)	Latitude (North) (DD˚ M.MMMM')	Longitude (East) (DD˚ M.MMMM')
5 June 2006 14:22 – 1555 Z	25 SPL	20	3548	20˚ 58.5433'	119˚ 59.4985'
16:57 – 1907 Z	25 SPL	40	3322	21˚ 01.5845'	119˚ 47.5720'
20:17 – 21:42 Z	25 SPL	60	3150	21˚ 04.4919'	119˚ 37.5956'
22:48 – 00:18 Z	25 SPL	80	3027	21˚ 07.436'	119˚ 26.606'
6 June 2006 01:20 – 02:36 Z	25 SPL	100	2860	21˚ 10.3041'	119˚ 16.6230
03:51 - 05:17 Z	27	120	2748	12˚ 13.2965'	119˚ 05.9726
06:27- 07:50 Z	25 SPL	140	2650	--	--
14:13 – 15:04	27	10	--	20˚ 57.690'	120˚ 02.656'
15:23 -	25 SPL	5	--	20˚ 57.001'	120˚ 05.398'

9.0 Basin Experiment (October 2006)

The final WISE cruise to recover the basin moorings was conducted 26-29 October 2006 on board the R/V OCEAN RESEARCHER 1. All acoustic equipment was recovered during this cruise, and initial data results for this deployment can be found in the previous chapter.

Table 59. Recovery cruise timeline (October 2006)

Date	Time	Event
10/26/06 (YD 299)	02:15 GMT	OR1 depart Kaohsiung
	23:51 GMT	B2 anchor released, recovery begins
10/27/06 (YD 300)	02:13 GMT	Source on deck, STAR array recovery
10/28/06 (YD 301)	01:00 GMT	No response from UW/APL ADCP mooring. Dragging underway to attempt recovery.
	18:12 GMT	Arrive at B1, commence CTD
	22:46 GMT	B1 anchor released, recovery begins
10/29/06 (YD302)	00:08 GMT	B1 recovery complete, returning to Kaohsiung
	10:40 GMT	Cat5 tropical hurricane at Luzon straight, heading into South China Sea . (100+ MPH winds)
	16:30 GMT	Arrive Kaohsiung harbor

A special thanks is given to our many Taiwanese friends: students, scientists, and ship's crew, that helped in the execution of this experiment, and the staff of the National Sun Yat-Sen University for providing working lab space and a staging yard for the many months spent in Kaohsiung.

Figure 57. Final mooring, final recovery.

Appendix A. B1 Monthly Temperature Plots

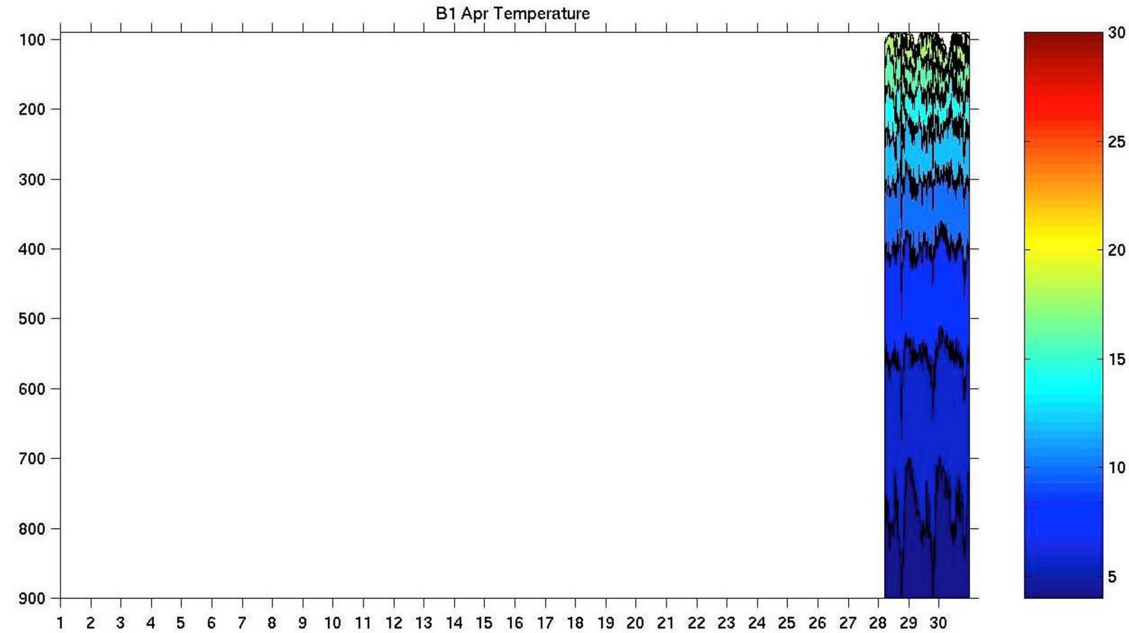


Figure 58. April 2005 temperatures (°C) at the B1 mooring, 100-900m.

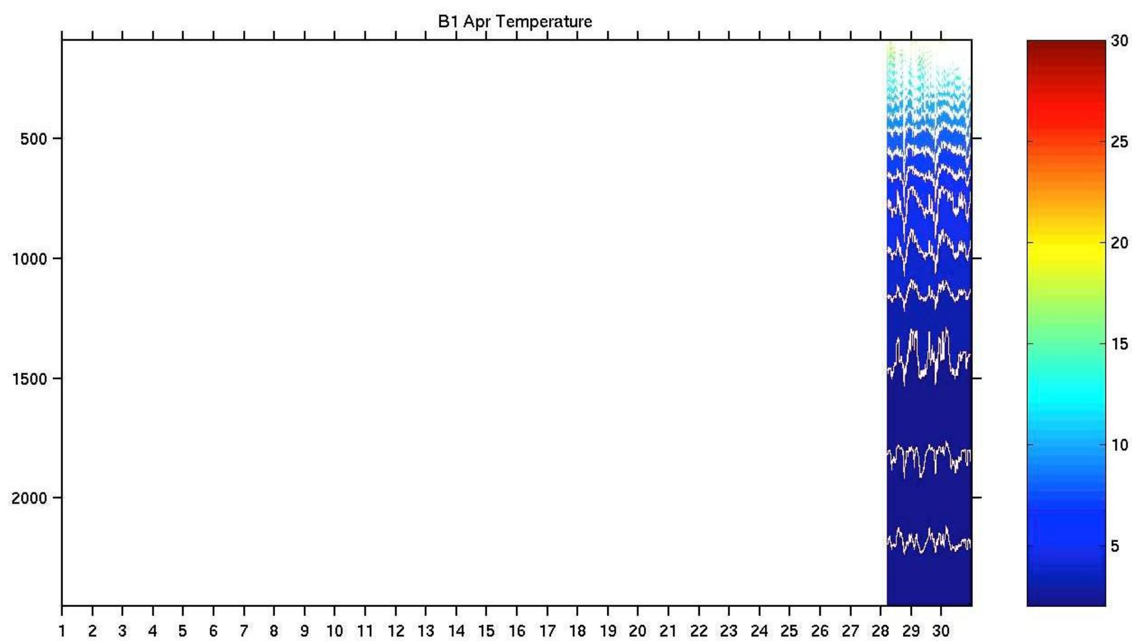


Figure 59. April 2005 temperatures (°C) at the B1 mooring.

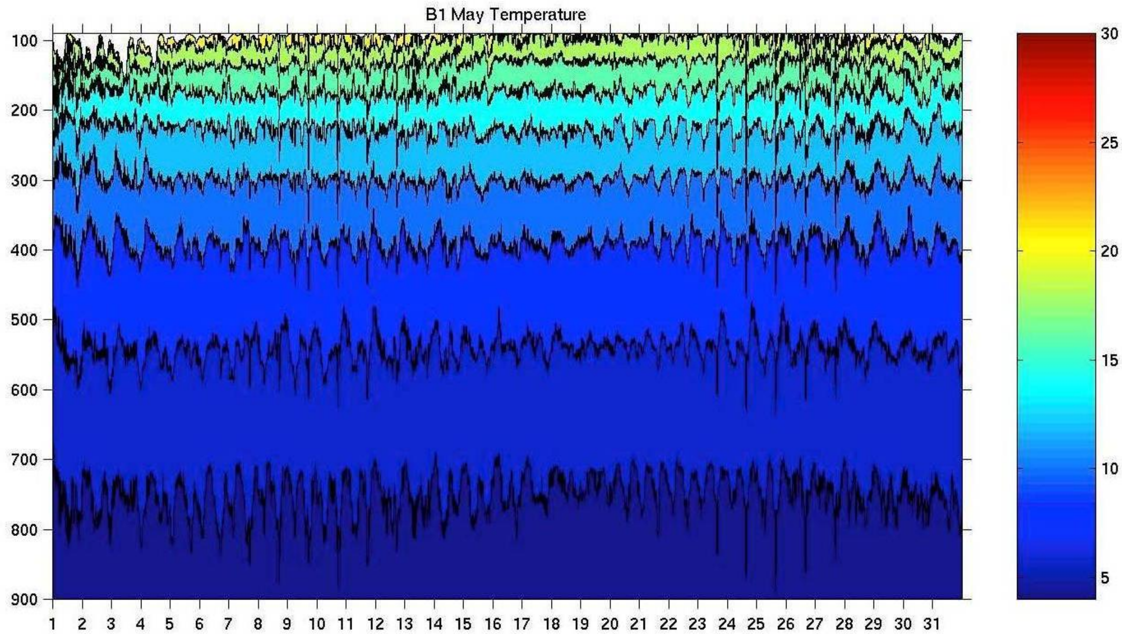


Figure 60. May 2005 temperatures (°C) at the B1 mooring, 100-900m.

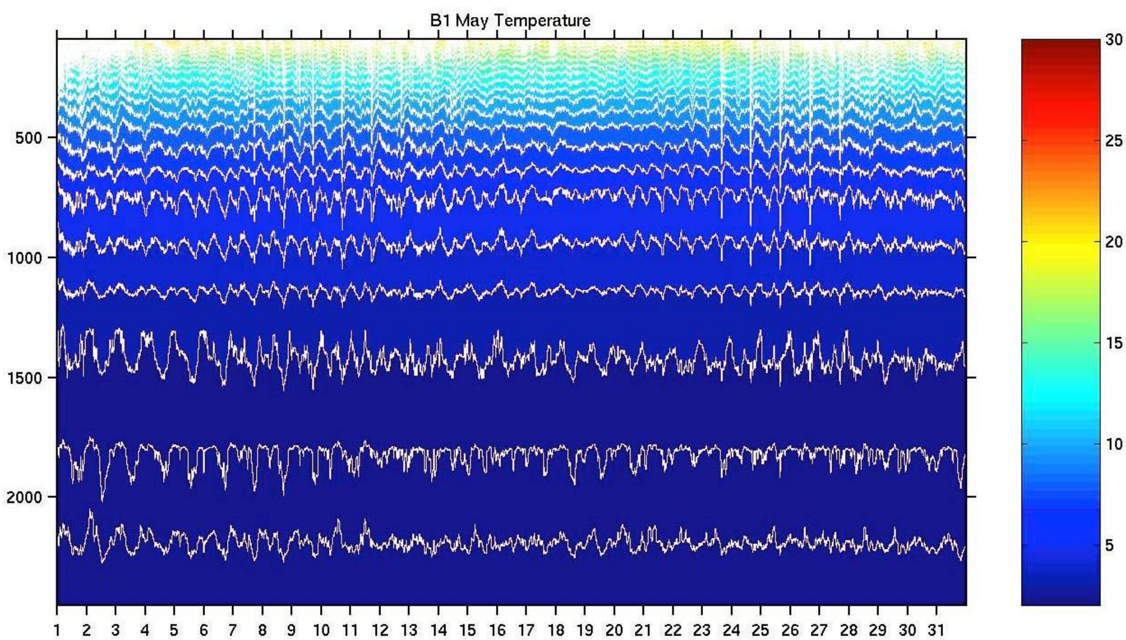


Figure 61. May 2005 temperatures (°C) at the B1 mooring.

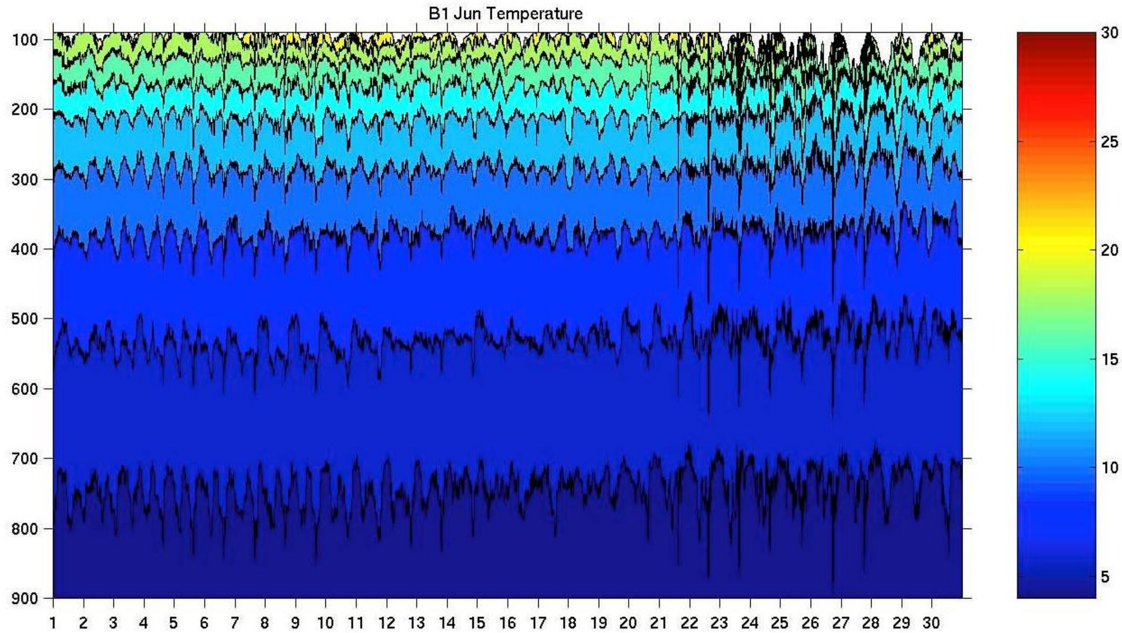


Figure 62. June 2005 temperatures (°C) at the B1 mooring, 100-900m.

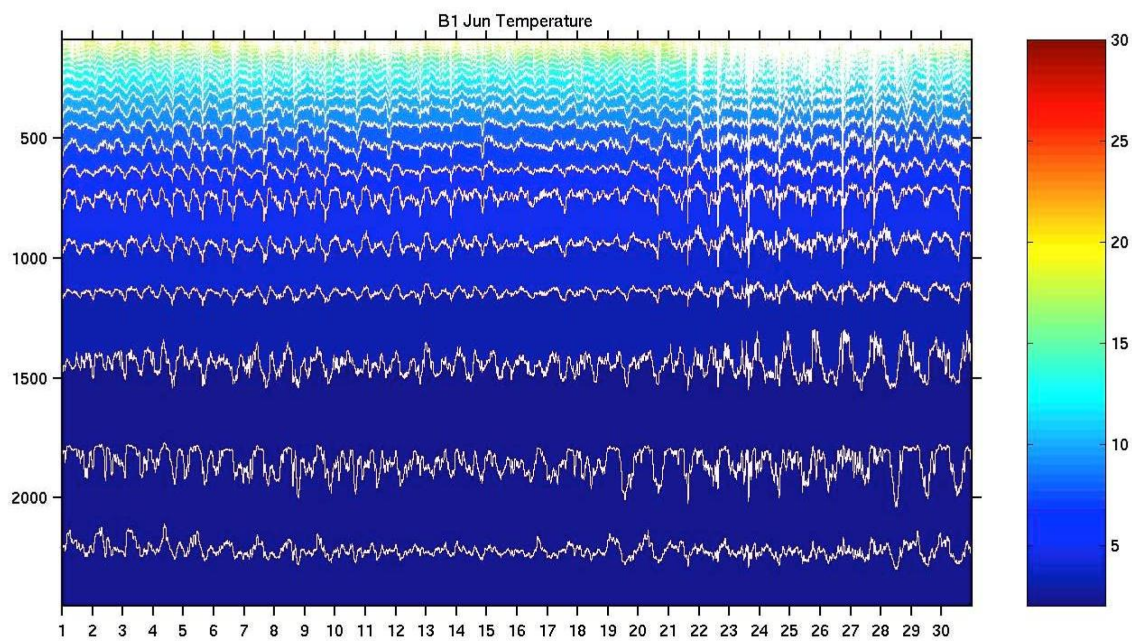


Figure 63. June 2005 temperatures (°C) at the B1 mooring.

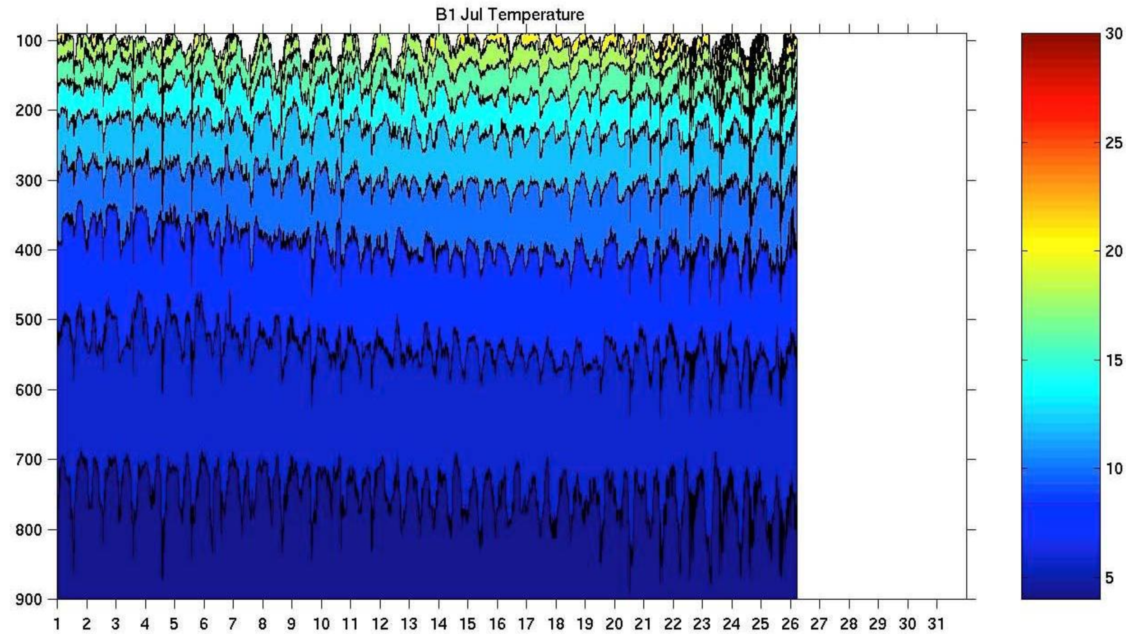


Figure 64. July 2005 temperatures (°C) at the B1 mooring, 100-900m.

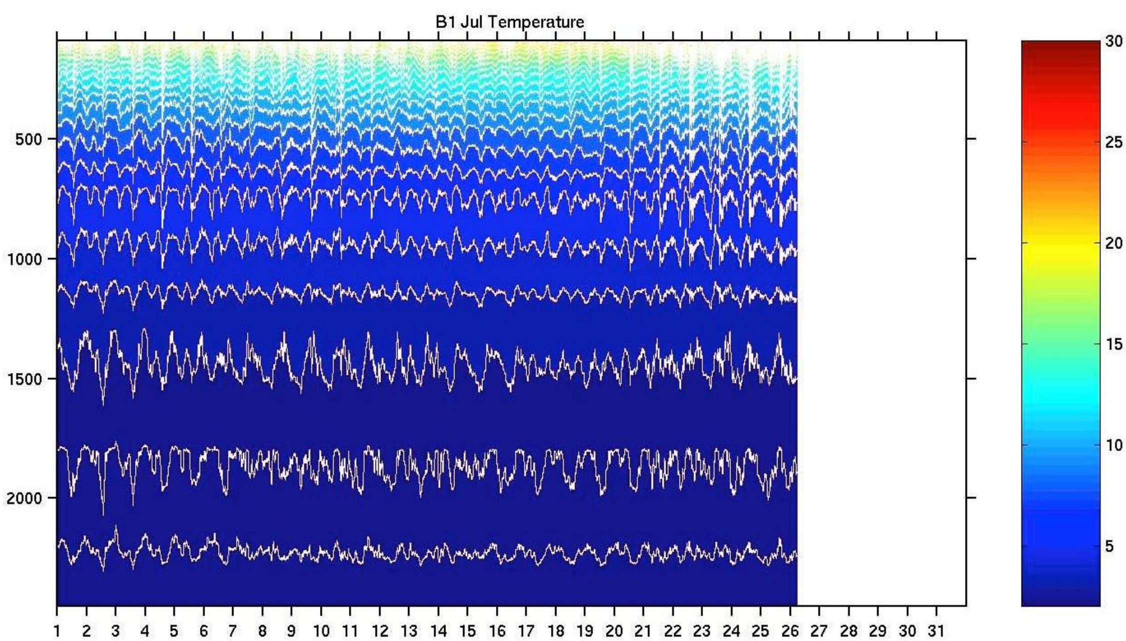


Figure 65. July 2005 temperatures (°C) at the B1 mooring.

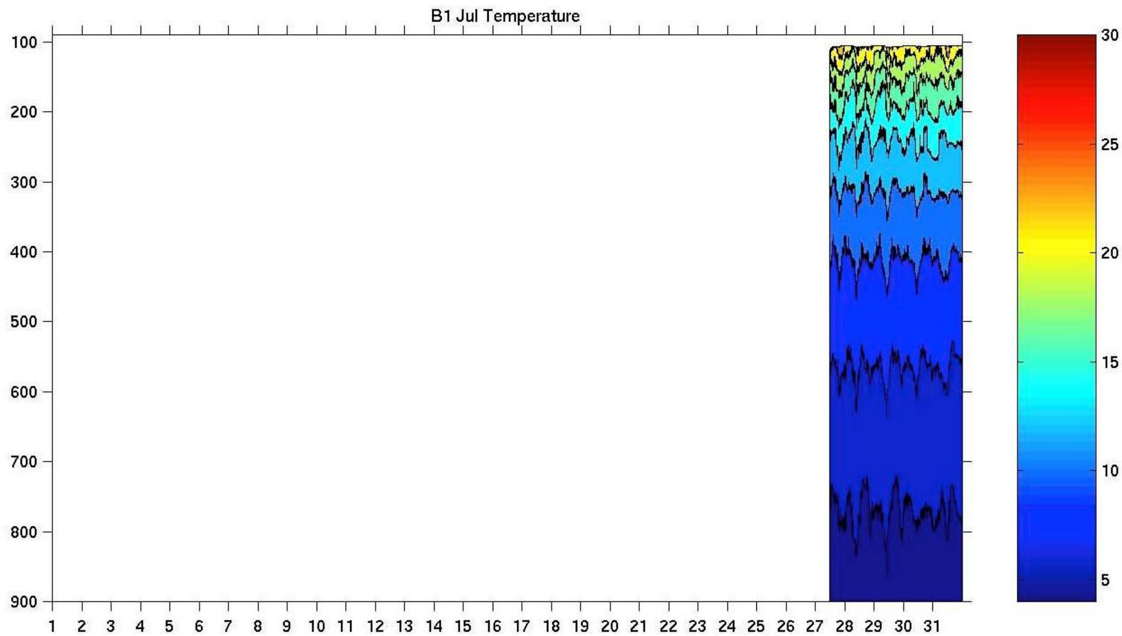


Figure 66. July 2005 temperatures (°C) at the B1 mooring, 100-900m (cont).

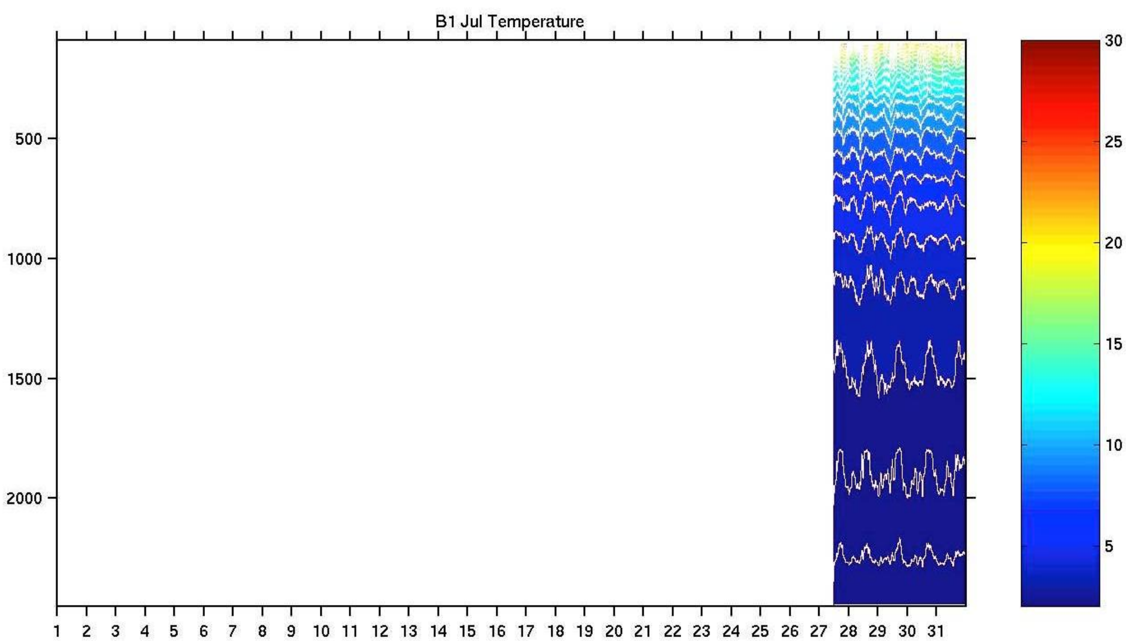


Figure 67. July 2005 temperatures (°C) at the B1 mooring (cont.).

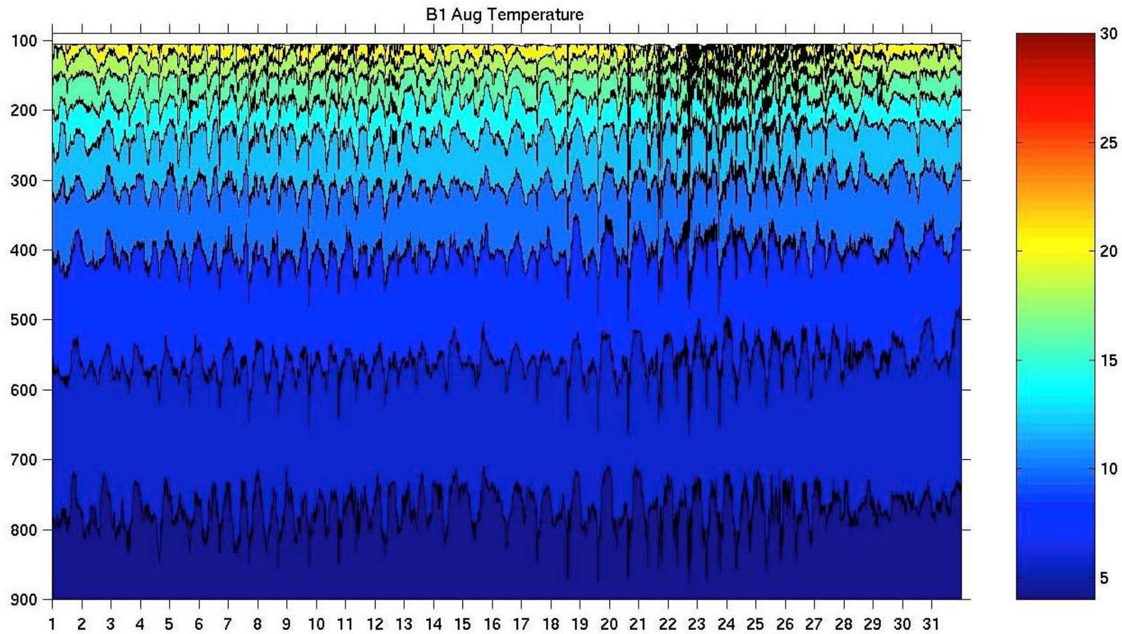


Figure 68. August 2005 temperatures (°C) at the B1 mooring, 100-900m.

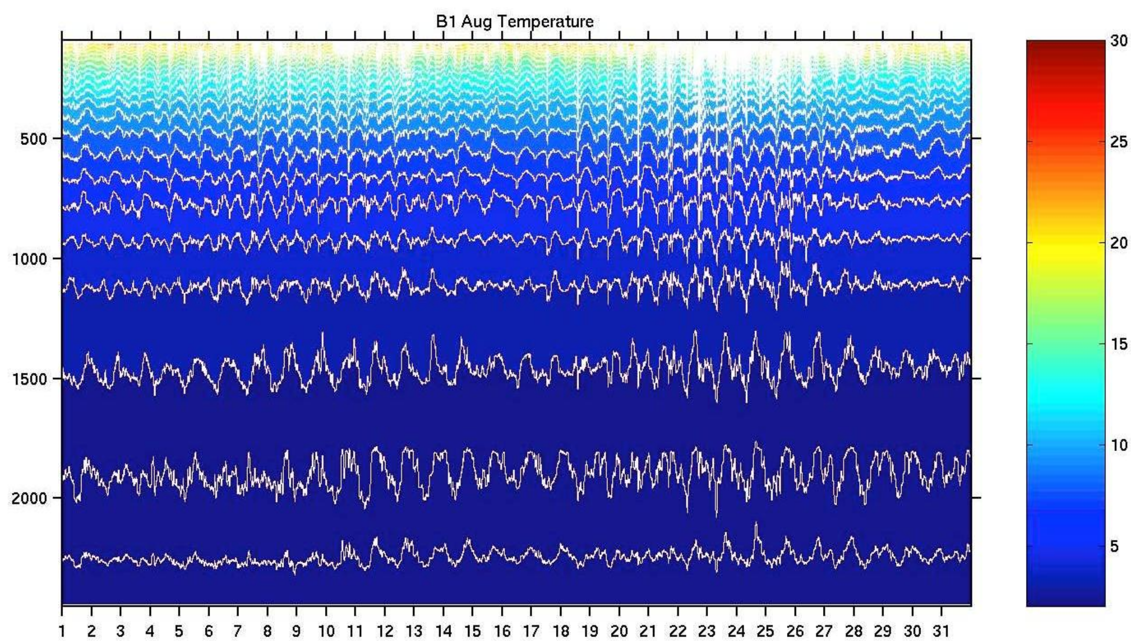


Figure 69. August 2005 temperatures (°C) at the B1 mooring.

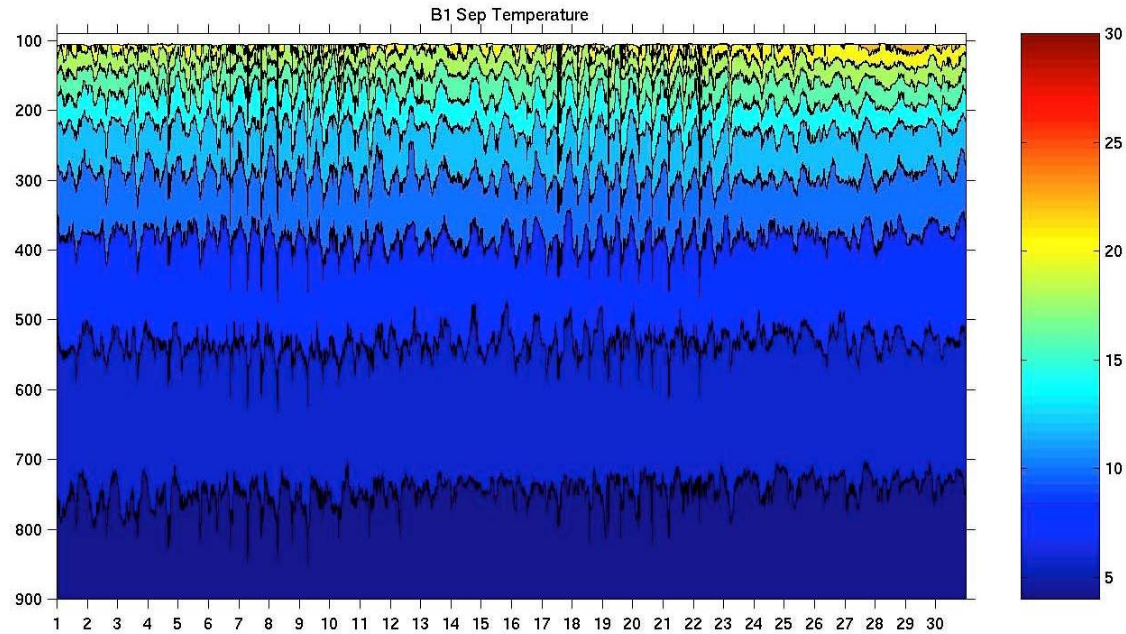


Figure 70. September 2005 temperatures (°C) at the B1 mooring, 100-900m.

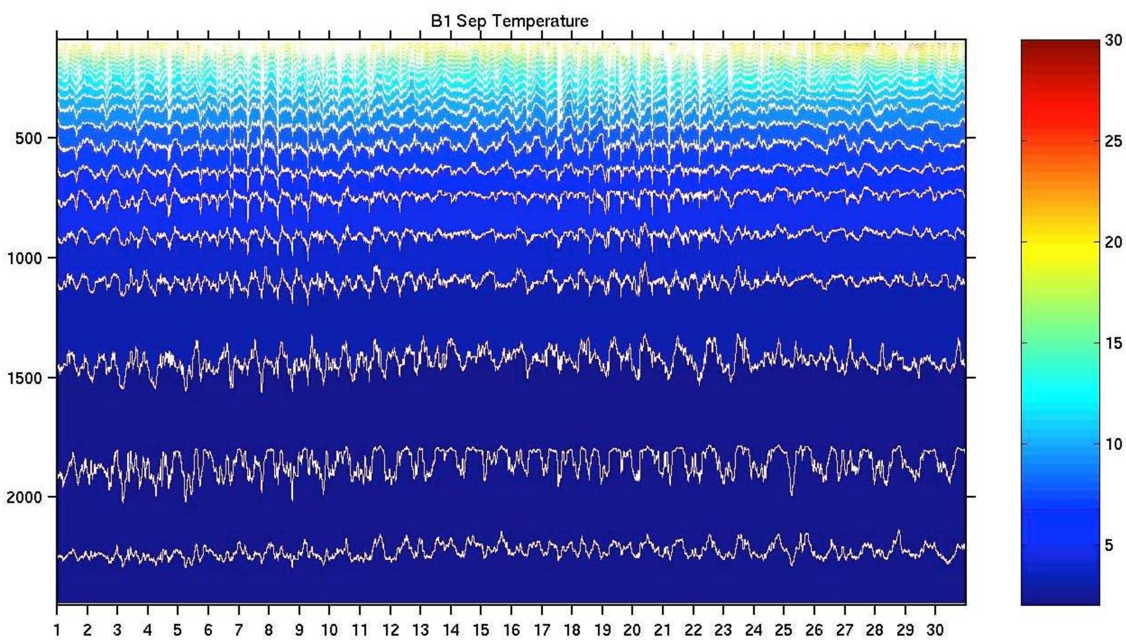


Figure 71. September 2005 temperatures (°C) at the B1 mooring.

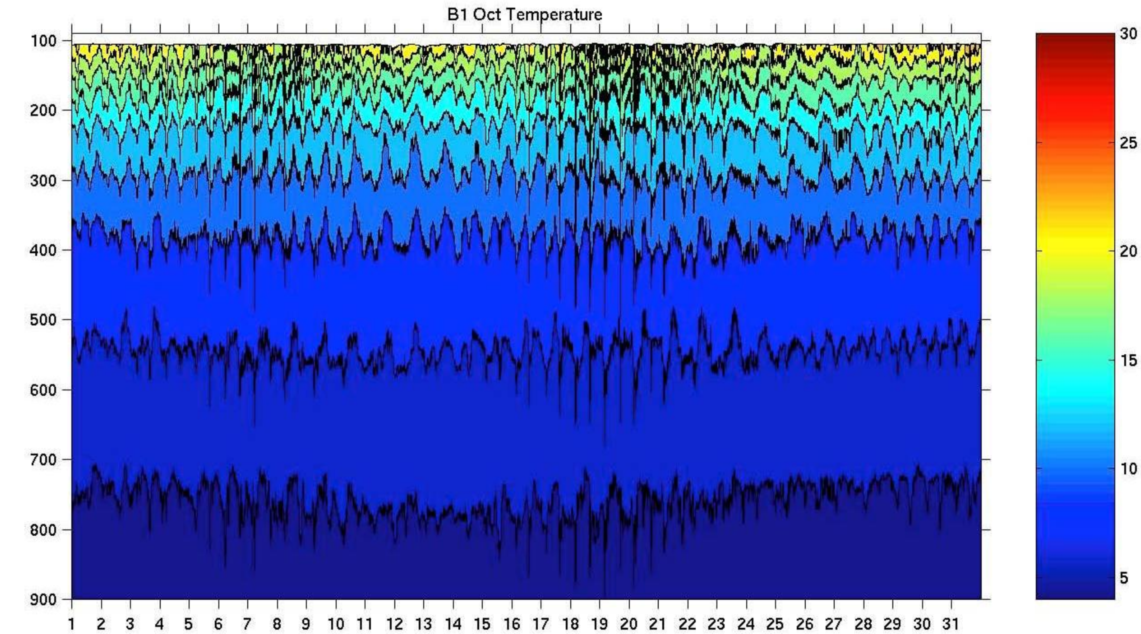


Figure 72. October 2005 temperatures (°C) at the B1 mooring, 100-900m.

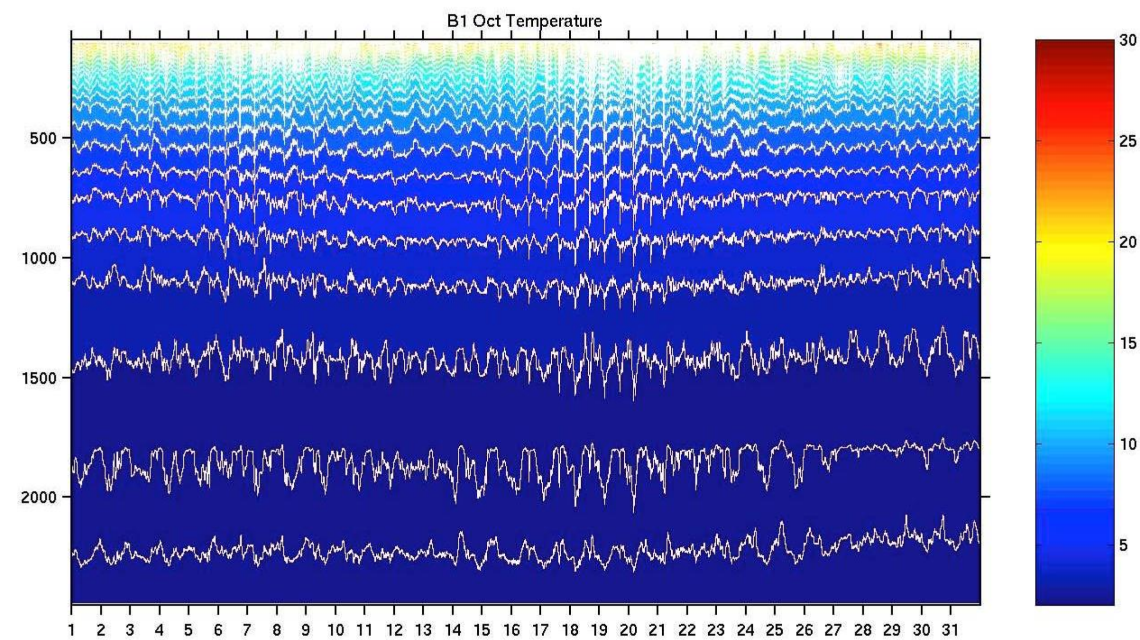


Figure 73. October 2005 temperatures (°C) at the B1 mooring.

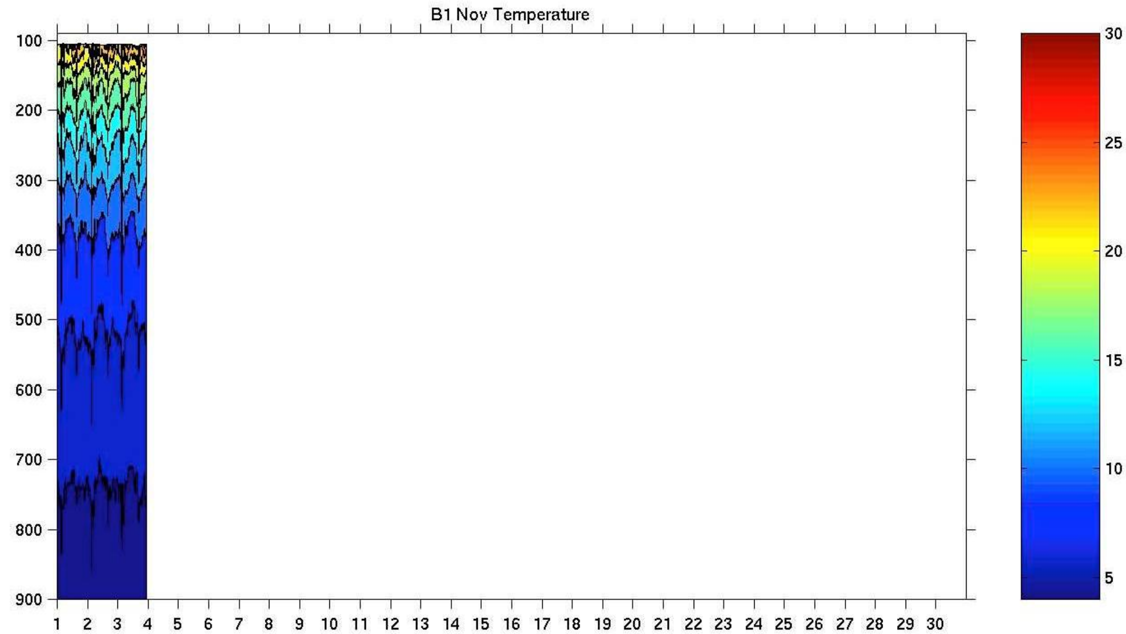


Figure 74. November 2005 temperatures at the B1 mooring, 100-900m.

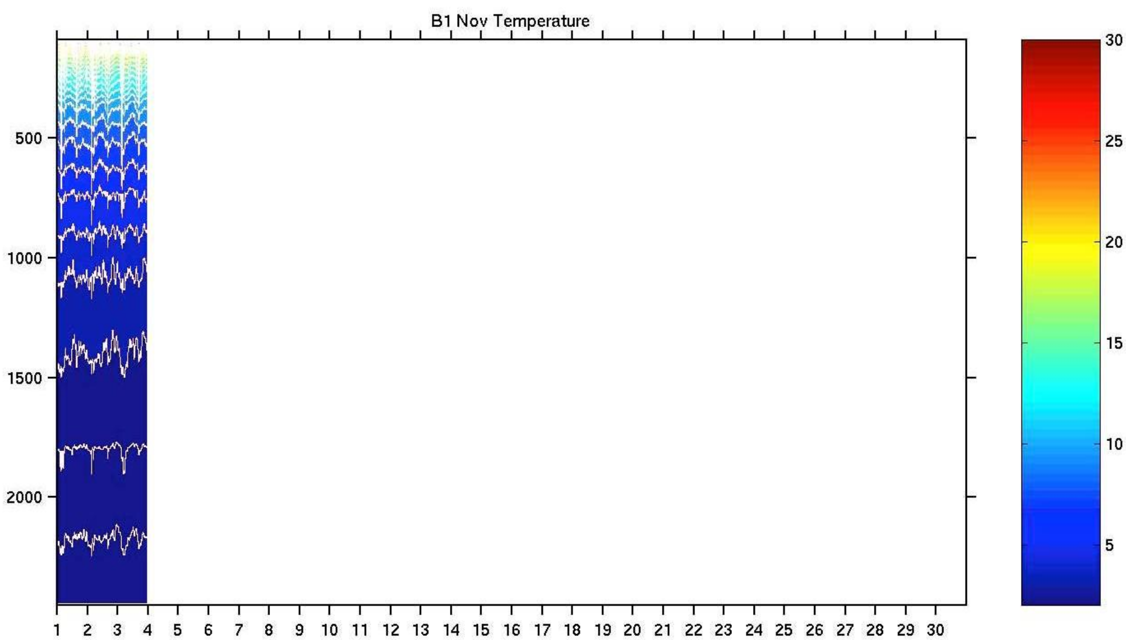


Figure 75. November 2005 temperatures (°C) at the B1 mooring.

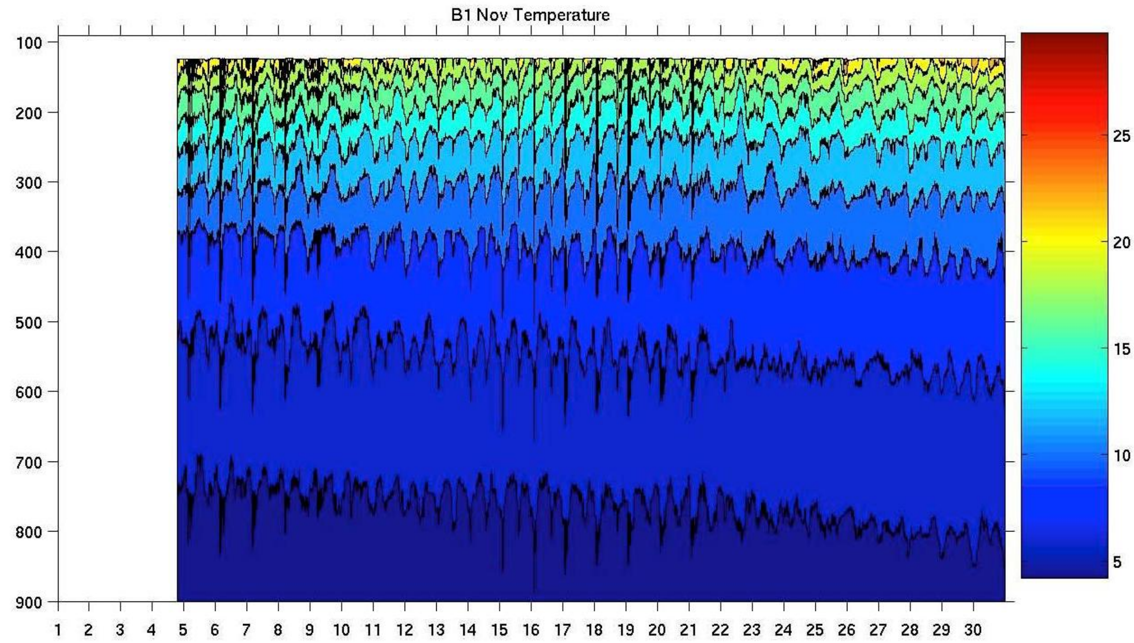


Figure 76. November 2005 temperatures (°C) at the B1 mooring, 100-900m (cont).

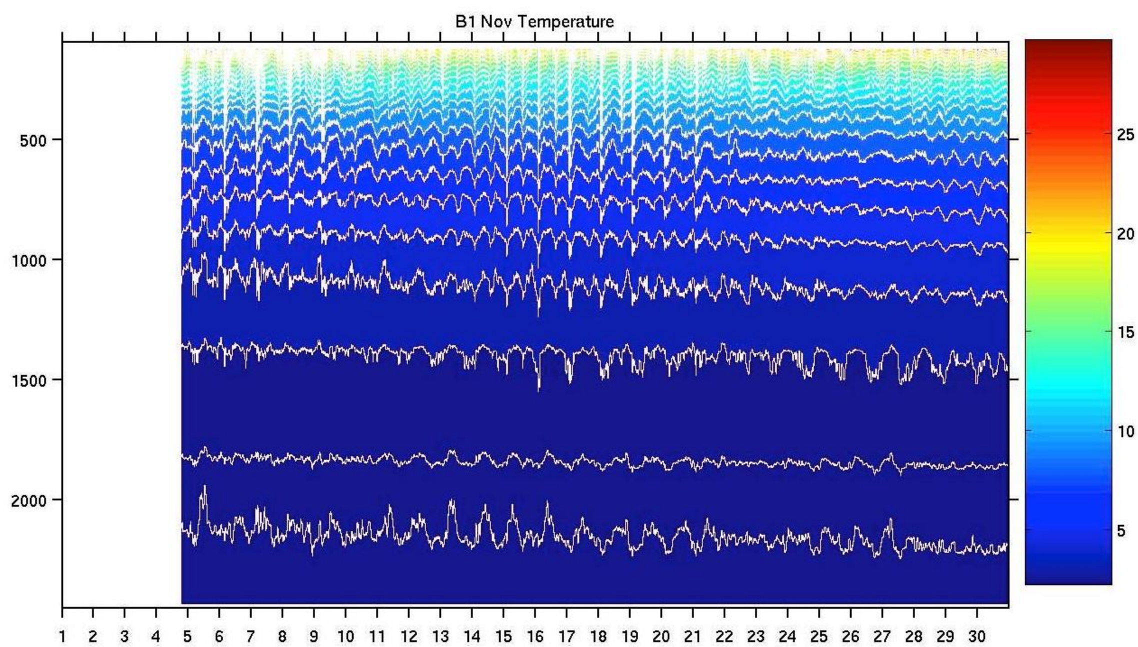


Figure 77. November 2005 temperatures (°C) at the B1 mooring.

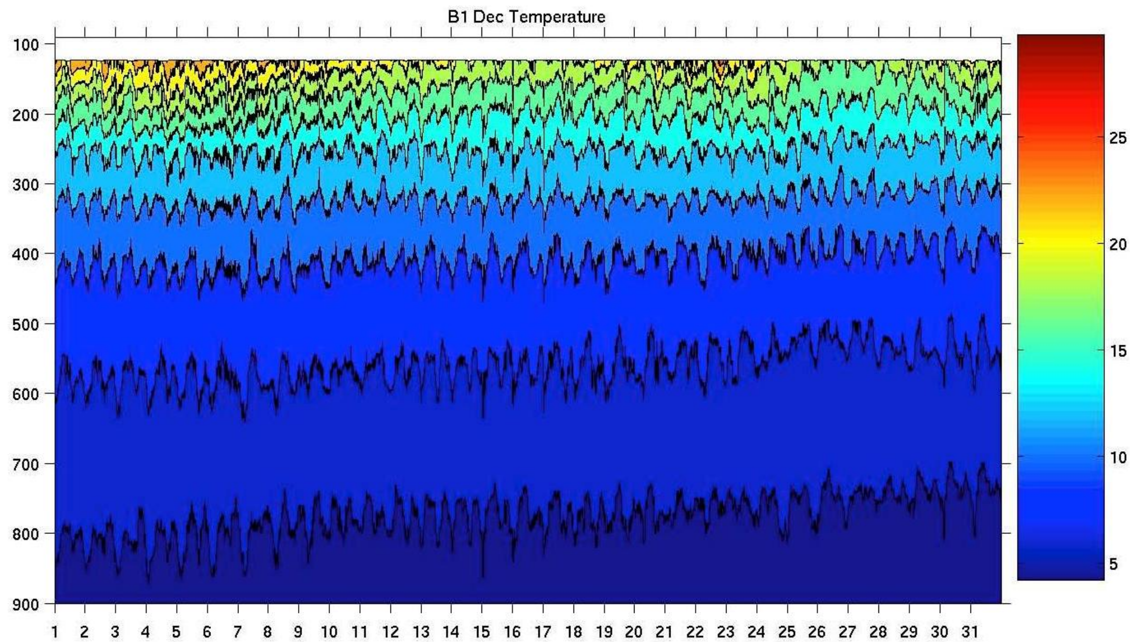


Figure 78. December 2005 temperatures (°C) at the B1 mooring, 100-900m.

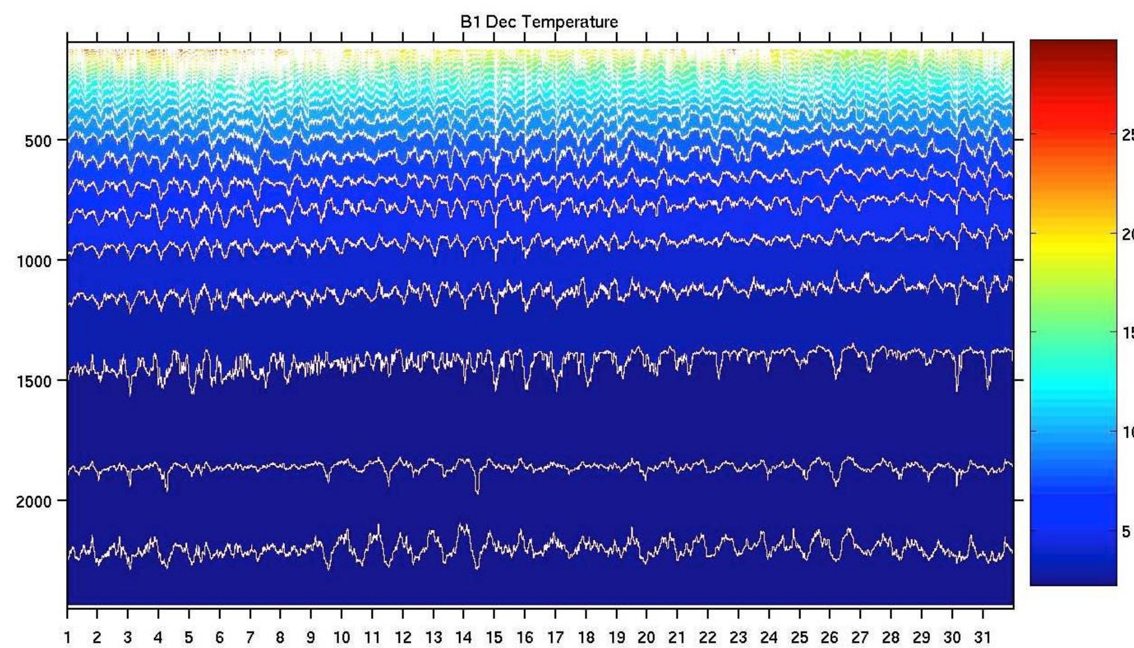


Figure 79. December 2005 temperatures (°C) at the B1 mooring.

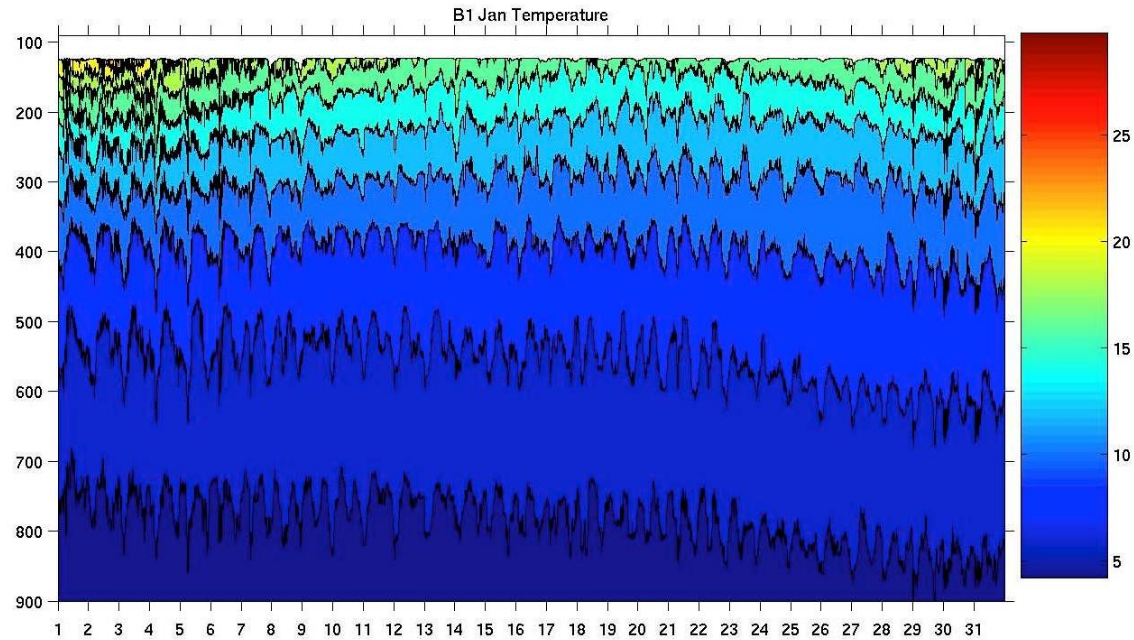


Figure 80. January 2006 temperatures (°C) at the B1 mooring, 100-900m.

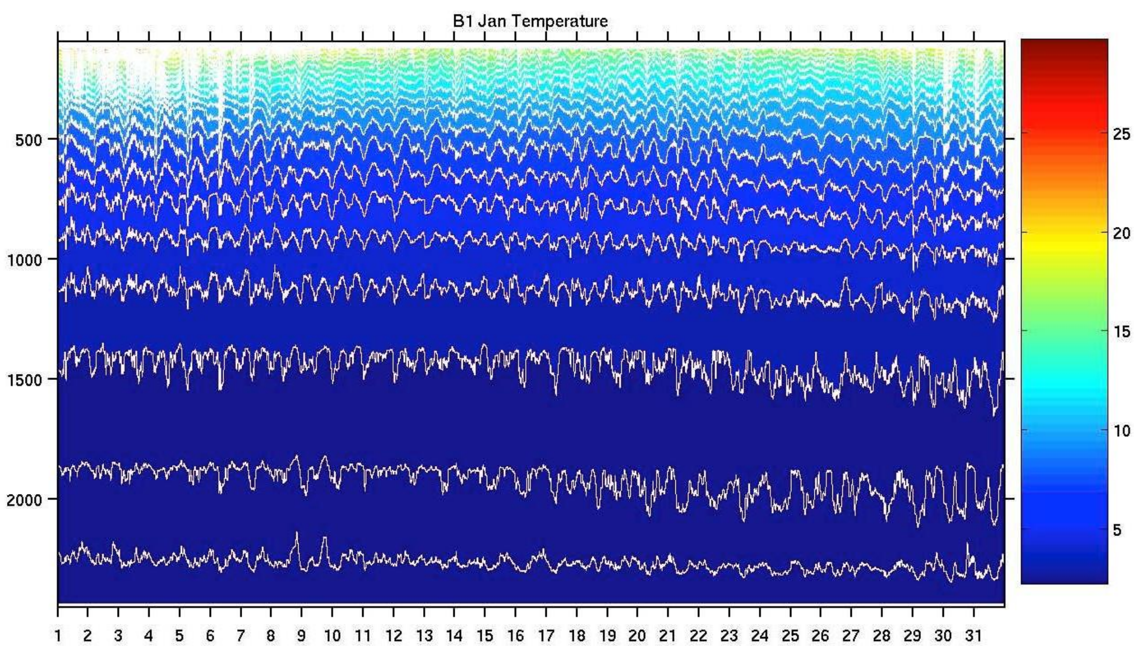


Figure 81. January 2006 temperatures (°C) at the B1 mooring.

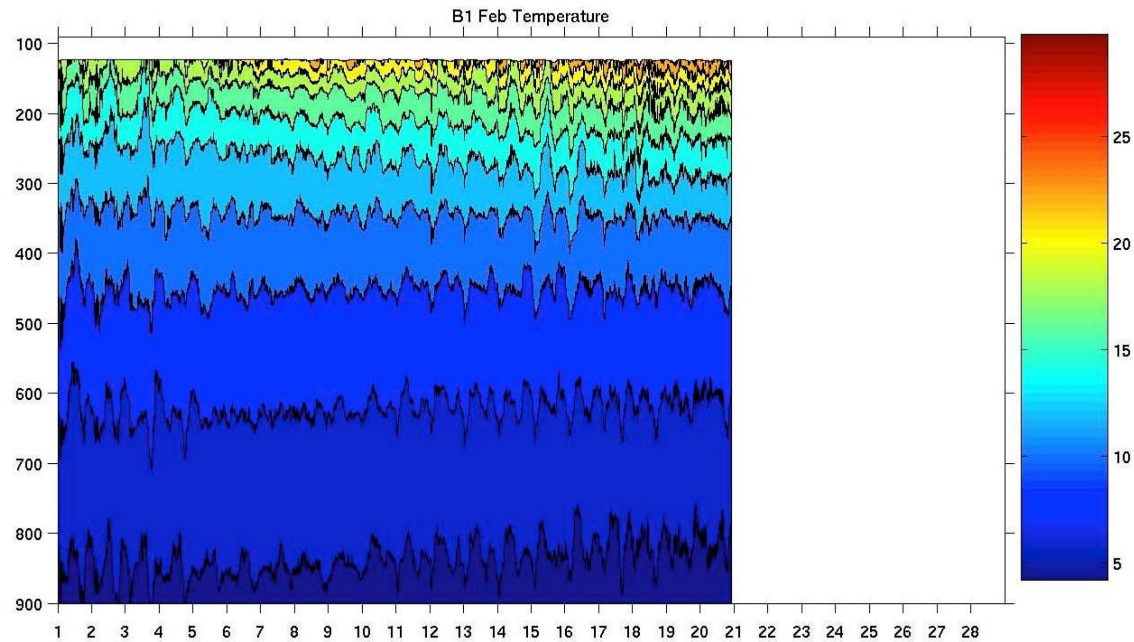


Figure 82. February 2006 temperatures (°C) at the B1 mooring, 100-900m.

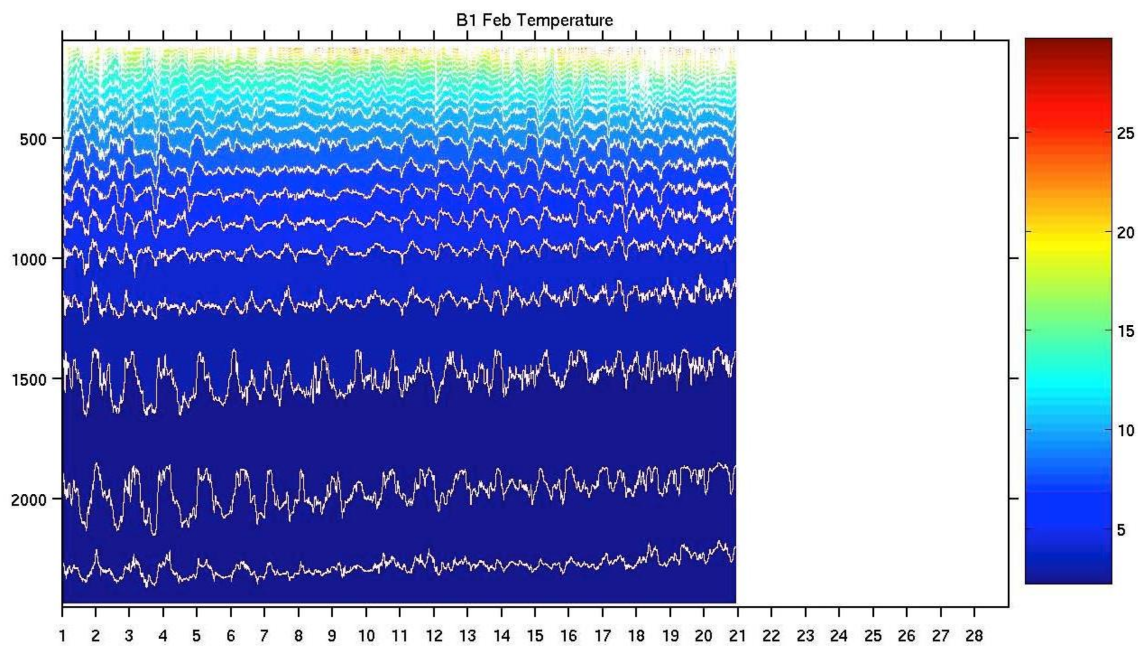


Figure 83. February 2006 temperatures (°C) at the B1 mooring.

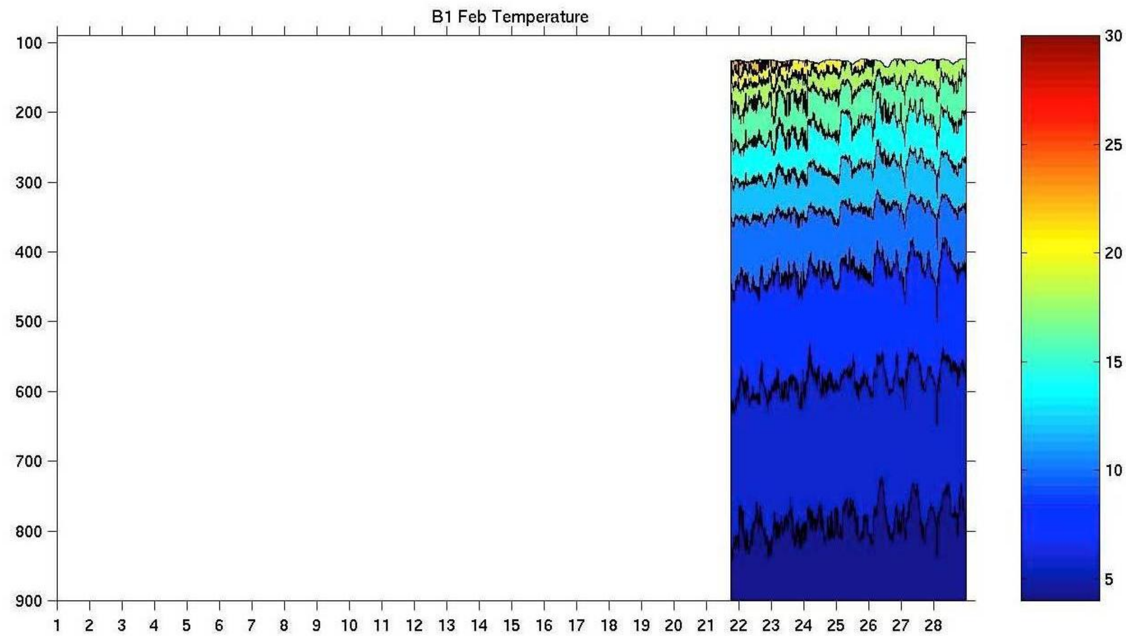


Figure 84. February 2006 temperatures (°C) at the B1 mooring, 100-900m. (Cont)

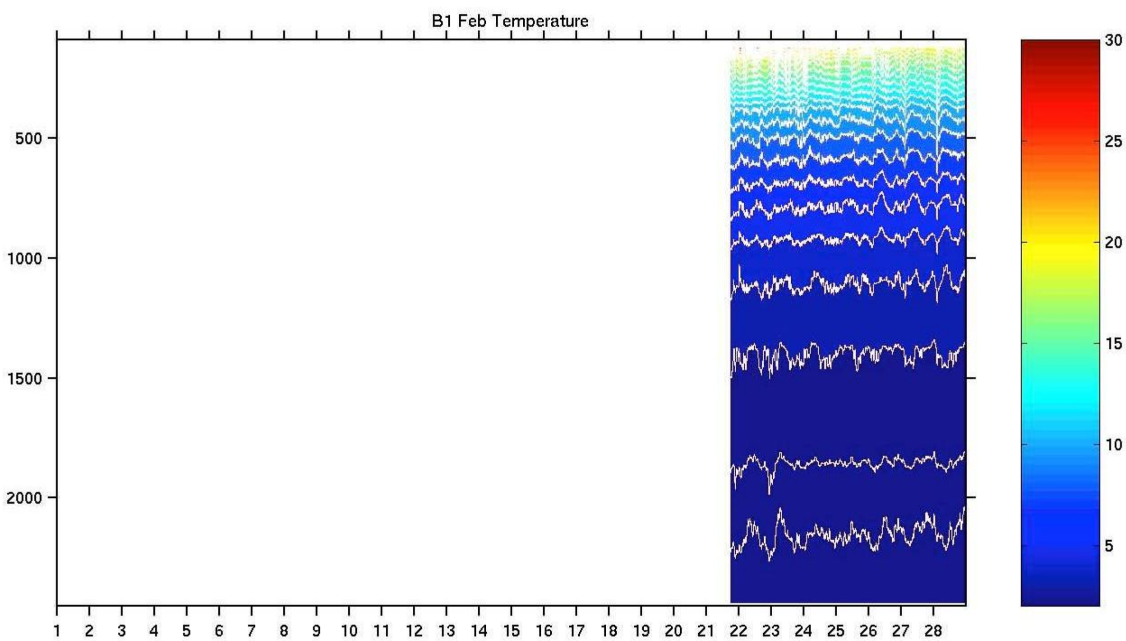


Figure 85. February 2006 temperatures (°C) at the B1 mooring (cont).

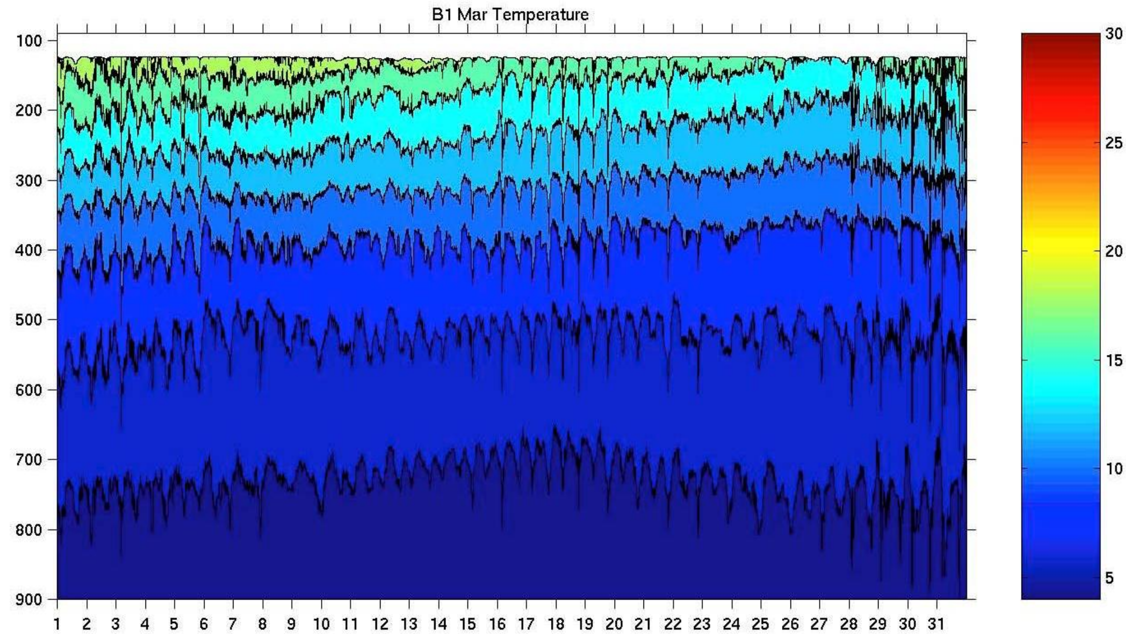


Figure 86. March 2006 temperatures (°C) at the B1 mooring, 100-900m.

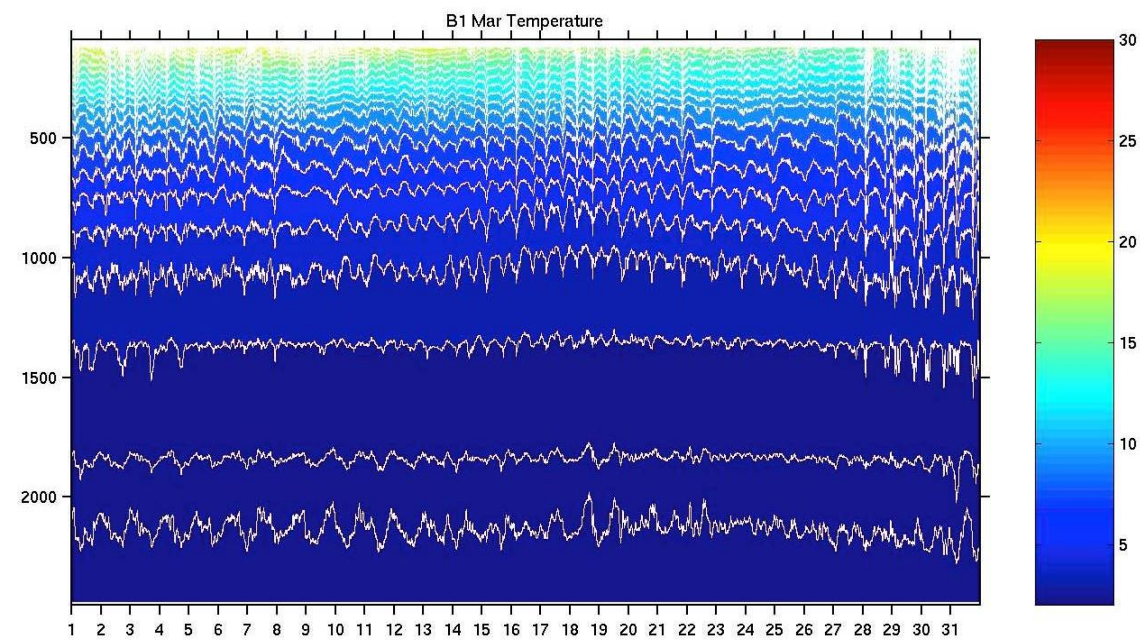


Figure 87. March 2006 temperatures (°C) at the B1 mooring.

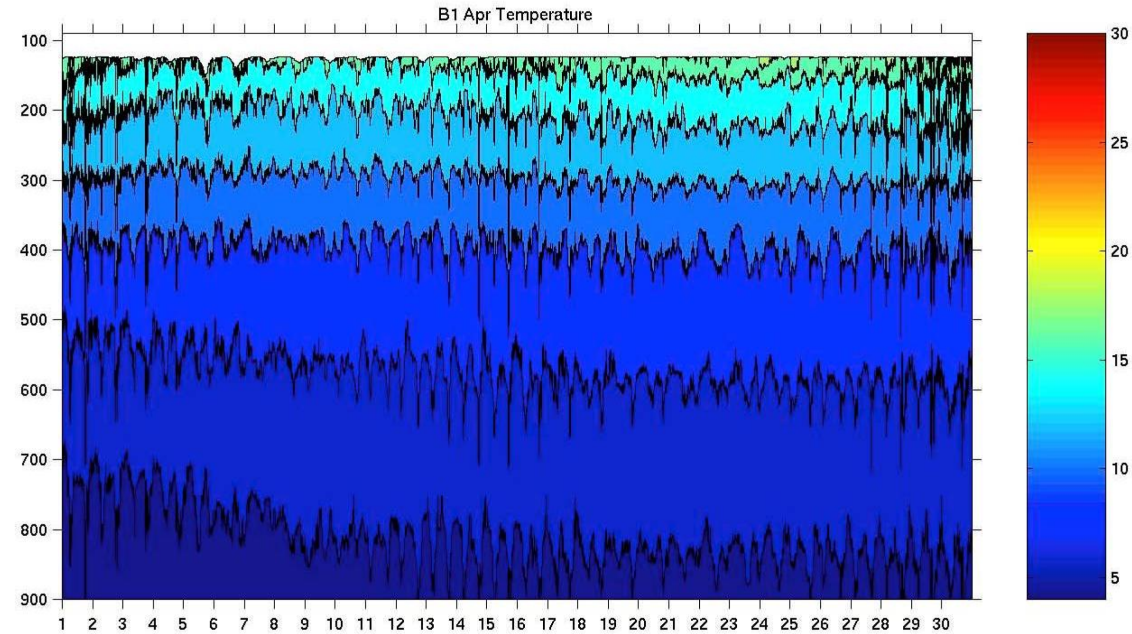


Figure 88. April 2006 temperatures (°C) at the B1 mooring, 100-900m.

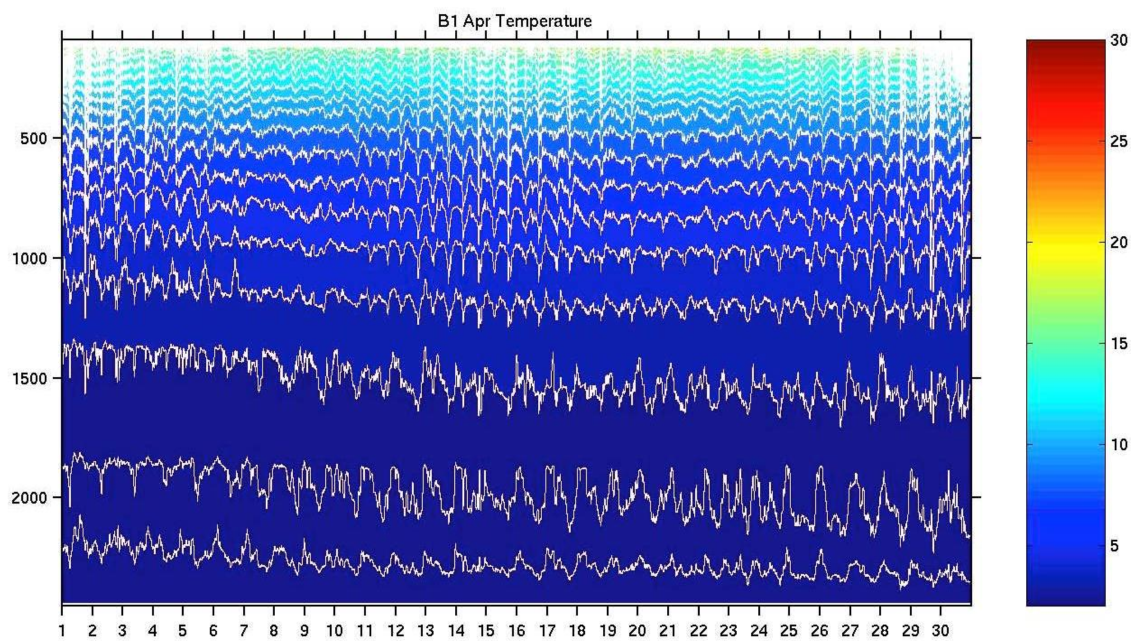


Figure 89. April 2006 temperatures (°C) at the B1 mooring.

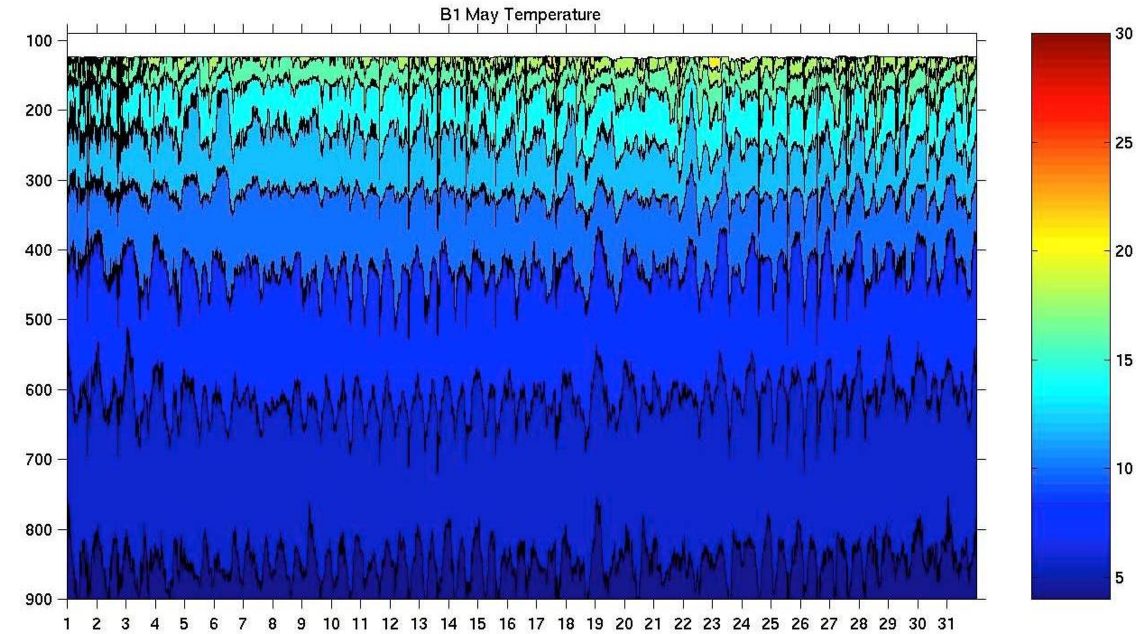


Figure 90. May 2006 temperatures (°C) at the B1 mooring, 100-900m.

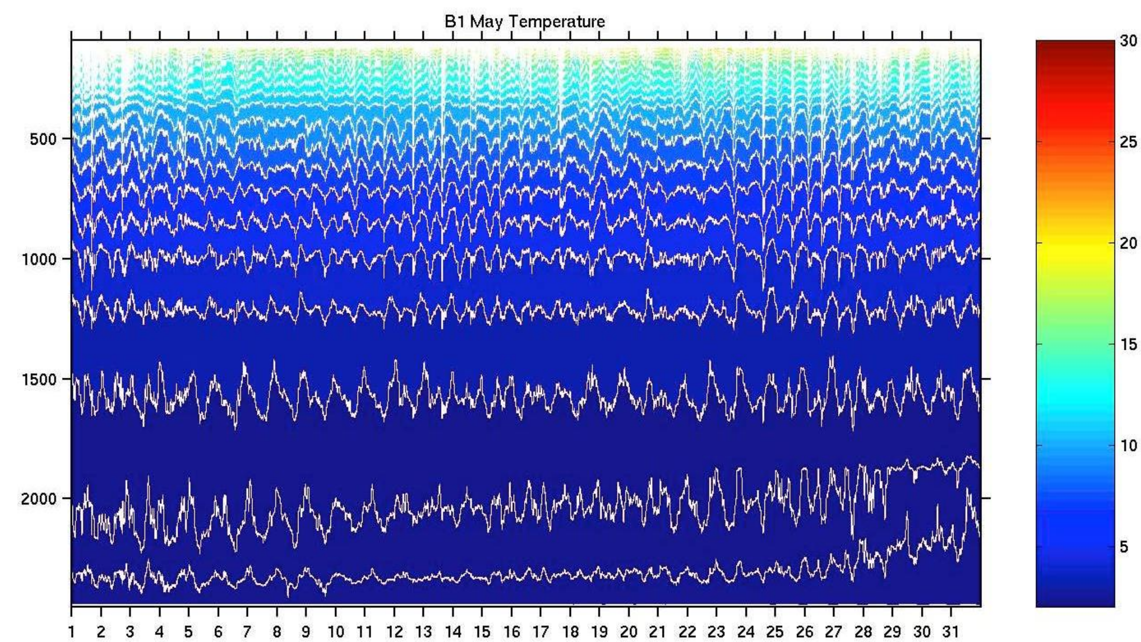


Figure 91. May 2006 temperatures (°C) at the B1 mooring.

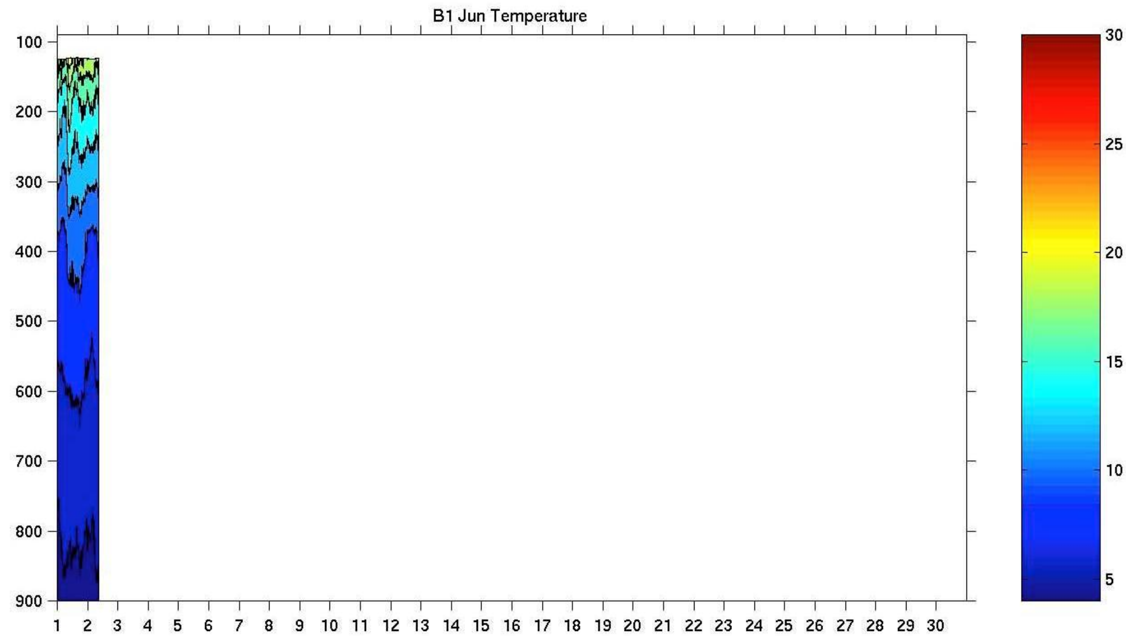


Figure 92. June 2006 temperatures (°C) at the B1 mooring, 100-900m.

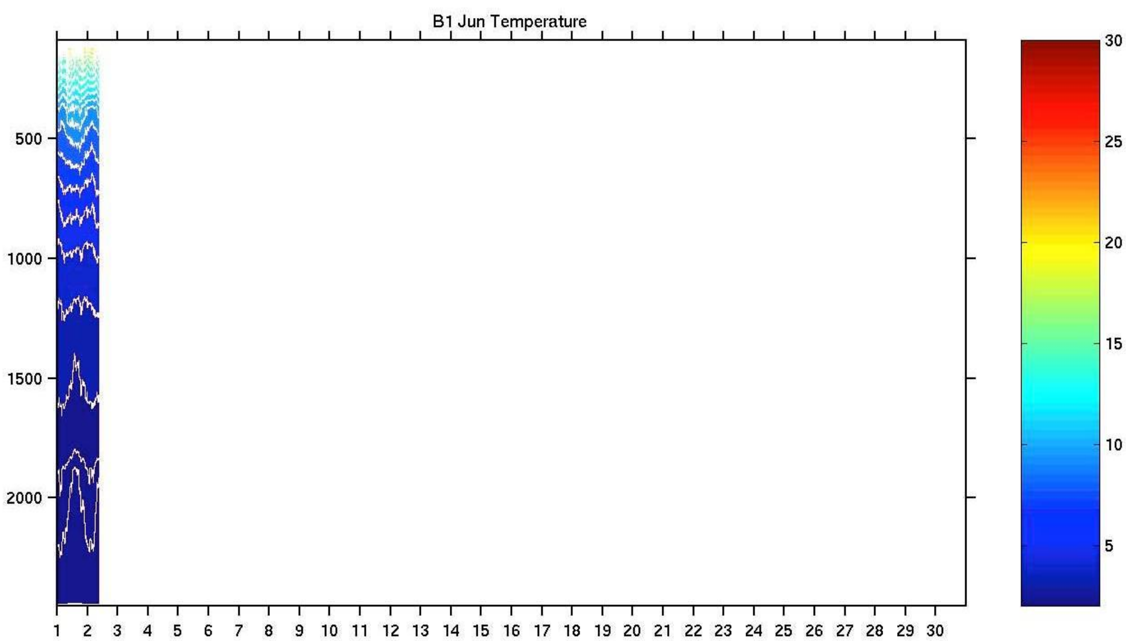


Figure 93. June 2006 temperatures (°C) at the B1 mooring.

Initial Distribution List

1. Defense Technical Information Center
Ft. Belvoir, VA 22060-6218

2. Dudley Knox Library
Naval Postgraduate School
Monterey, CA 93943-5100

3. Chris Miller
Naval Postgraduate School
Monterey, CA 93943

4. Marla Stone
Naval Postgraduate School
Monterey, CA 93943

5. Ching-Sang Chiu
Naval Postgraduate School
Monterey, CA 93943

6. D. Benjamin Reeder
Naval Postgraduate School
Monterey, CA 93943